THE INSTITUTE OF PHYSICS

BULLETIN

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Appointments Vacant

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

THE COLLEGE OF AERONAUTICS

Applications are invited for the appointment of SENIOR LECTURER in the Department of Materials. The post, which becomes vacant in 1960, involves teaching at postgraduate level in subjects of relevance to aeronautical engineering, and previous experience in this field will be an advantage. Candidates should be graduates in one of the basic relevant sciences, such as physics, chemistry or metallurgy, and will be expected to engage in research and to supervise the research work of students, as well as assist in the organization and development of the various activities of the Department. Contributions to original research, and a higher degree in an appropriate subject are desirable. Salary in scale of £1,700 × £75 – £2,150 p.a. with superannuation under F.S.S.U. and family allowance. Commencing salary within the prescribed scale will depend upon age, qualifications and experience. Consideration given to housing requirements. Applications giving full particulars and quoting the names of three referees, to the Recorder, The College of Aeronautics, Cranfield, Bletchley, Bucks. Further particulars available.

SUNDERLAND EDUCATION AUTHORITY

THE TECHNICAL COLLEGE

Applications are invited for the post of LECTURER in physics. Applicants should have honours degree: research or industrial experience an advantage. Salary: £1,370 × £35–£1,550 (incremental credit for approved previous experience). Further particulars and forms of application from the Registrar, The Technical College, Sunderland. Canvassing will disqualify. W. Thompson, Director of Education, Education Offices, 15 John Street, Sunderland.

JOSEPH LUCAS (GROUP SERVICES) LTD.

have a vacancy for a YOUNG GRADUATE to take part in interesting work on theoretical and experimental problems in elasticity in their laboratory at Marston Green, Birmingham. Applicants should possess an honours degree preferably in physics, but those possessing a qualification in mathematics will also be considered. Previous industrial or research experience is not essential. Salary according to qualifications and experience but not less than £750 per annum. The post is permanent and pensionable. Five day week. Apply in writing, stating age, qualifications and experience to the Personnel Manager, Joseph Lucas Ltd., Great King Street, Birmingham, 19, quoting reference PM/GR/314.

A senior and experienced MICROWAVE PHYSICIST is required by Laboratories RCA Ltd., to establish a research program in its Zürich Laboratories presently engaged in other solid state research. Write to Box A.S.1289, Austin Knight Advertising Ltd., 212A Shaftesbury Avenue, London, W.C.2.

PHYSICISTS required for Research and Development Establishments in Ministry of Supply with well equipped laboratories mainly in Southern England offering wide range of work including solid state physics, radio astronomy, space research, low temperature physics, aircraft projects, ballistic missiles, guided weapons, advanced computing techniques, optics, electronics, radar, telecommunications, gas turbines, aerosols, industrial compressed gases. Appointments in grades of (*a*) Senior Scientific Officer (£1,166 – £1,380), (*b*) Scientific Officer (£615 – £1,090). Starting salary according to experience. Superannuation under F.S.S.U. 1st or 2nd class honours degree or equivalent required and for (*a*) at least three years' postgraduate research experience. Good promotion prospects. Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A.437/9A/NB.

VALVE ENGINEERS

The English Electric Valve Company as the foremost specialized valve manufacturer in the United Kingdom wishes to expand its development work on

Microwave Valves

Photoconductive Devices

Semiconductor Power Rectifiers

Storage Tubes

Large and small Transmitter Valves

The Company wishes to engage the services of several experienced VALVE ENGINEERS for this work and therefore invites applications from suitably qualified people.

Brief details of experience, qualifications and age should be sent to : Central Personnel Services, Marconi House, Strand, London, W.C.2, quoting reference PB 1506B.

PHYSICIST AND PHYSICAL OR INORGANIC CHEMIST required at Building Research Station (D.S.I.R.), Garston, Nr. Watford, Herts., as follows: Physicist for basic research in heat transfer / aerodynamic / convection processes defining the microclimate in buildings. (Ref. A139/8A). Physical or Inorganic Chemist or Physicist for programs on relation of chemical and physical constitution of inorganic and organic building materials to their performance in use. Opportunities to develop or make use of existing techniques, e.g. in silicate chemistry, rheology, surface chemistry, X-ray crystallography, or study of phase equilibria relevant to building material compositions. Facilities for continuing laboratory work on pilot scale or in field. (Ref. F33/9.) Qualifications for each post : 1st or 2nd Class Honours degree. (At least three years' postgraduate experience required for Senior Scientific Officer.) Salary ranges : Scientific Officer (Men) £615 – £1,090. (Postgraduate experience and National Service considered in assessing starting salary.) Senior Scientific Officer £1,166 – £1,380. Excellent prospects of advancement. Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1 (quote reference). Closing date November 24, 1959.

UNIVERSITY OF SYDNEY

Applications are invited for the following positions in the School of Physics. 1. SENIOR LECTURESHIP IN PHYSICS. Applicants should be specialists in astronomy but should have, in addition, a strong background in physics. The appointee will be in charge of the new 40-inch reflector to be obtained for the School of Physics. 2. THREE LECTURESHIPS IN EXPERIMENTAL PHYSICS. One appointment will be made in the field of nuclear physics and two appointments in the filed of electronics. 3. ONE LECTURESHIP IN THEORETICAL PHYSICS. The salary for a Senior Lecturer is within the range £A2,200 × £80 – £2,600 per annum ; for a Lecturer within the range £A1,500 × £90 – £2,100 per annum. In each case cost of living adjustment will be allowed. The salary is subject to deductions under the State Superannuation Act. The commencing salary will be fixed according to the qualifications and experience of the successful applicant. Under the Staff Members' Housing Scheme in cases approved by the University and its Bankers, married men may be assisted by loans to purchase a house. Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close on December 15, 1959.

BP has a vacancy for a PHYSICIST in the Exploration Research Laboratory at Sunbury-on-Thames. He will be a member of a group working on the propagation of elastic waves through rocks, and he can expect to do a certain amount of field work. A good honours degree in physics or applied mathematics is required, with at least three years of postgraduate research experience. Some knowledge of electronics is very desirable. Salary according to age, qualifications and experience. Non-contributory Pension Fund. Housing Scheme. Removal expenses paid in certain cases. Luncheon Club. Write giving full details of experience and qualifications quoting H.4997, to The Manager, Recruitment Branch, The British Petroleum Company Ltd., BP House, Ropemaker Street, London, E.C.2.

UNIVERSITY COLLEGE OF NORTH STAFFORDSHIRE

Applications are invited for the MULLARD RESEARCH FELLOWSHIP in physics, recently founded by Mullard Ltd., for research in various branches of solid-state physics with particular reference to defects, semiconductor or surface properties. Research facilities at present available include thermionic emission techniques and investigation by magnetic resonance. Applicants should preferably hold a Ph.D. degree or have had equivalent research experience. Appointment will be for a period of up to three years. Value within the range £700 to £850 according to qualifications and experience, plus F.S.S.U. and family allowances. Application forms and further particulars from the Registrar, The College, Keele, Staffs., to whom completed forms should be sent not later than November 30, 1959.

G. V. PLANER LTD. have two high level research vacancies on important Ministry and industrial projects. Semiconductors : PHYSICIST/CHEMIST specialized in semiconductors. Electrical Ceramics : A CERAMICIST, Physicist or Chemist with experience in titanate dielectrics, piezoelectrics or ferrites. Both appointments are highly progressive and carry attractive salaries according to experience and qualifications. Apply in confidence : Dr. G. V. Planer, G. V. Planer Ltd., Windmill Road, Sunbury-on-Thames, Middlesex.

UNIVERSITY OF QUEENSLAND
PROFESSOR OF APPLIED MATHEMATICS

Applications are invited for the above position. Applicants should have had experience of teaching at University level and have made significant original contributions to some branch or branches of applied mathematics. Salary £A3,500 p.a. Further particulars and application forms are obtainable from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1, or from the Registrar, University of Queensland, Brisbane, Queensland, Australia. Applications close, in Australia and London, on December 15, 1959.

CHEMISTS AND PHYSICISTS

RESEARCH AND DEVELOPMENT

Applications are invited by BRITISH NYLON SPINNERS for vacancies in their Research Department ; continued expansion in the Company's research efforts has led to this need for additional staff. Work is going on in a wide variety of topics. Chemical investigations include exploratory organic and physico-chemical studies directed towards the synthesis of new fibre-forming polymers, polymerization mechanisms and catalysts, general work of a physico-chemical nature on polymer chemistry, applied work on surfaces, and thermal and photochemical degradation problems. Physicists are needed for fundamental work on the thermodynamics of polymer systems, for work on the solid state somewhat akin to the semi-conductor field, and for a classical properties-of-matter approach to the physics of textile yarns and fabrics. In addition fundamental and applied problems of melt-spinning technology are being investigated by qualified staff whose initial training has been in either chemistry or physics. These activities are all at the Company's headquarters near Pontypool, where the facilities and equipment available for doing work of high quality are all that can be desired. Other conditions of employment are on a suitably high plane, and the opportunity of combining all this with living and working in the delightful Monmouthshire countryside is most unusual. Rented houses are available in the area, and removal expenses are paid, so that married men need anticipate little difficulty in resettling their families.

Applications from Honours Graduates, preferably with a few years' research or development experience, should be addressed to :

The Personnel Manager,
BRITISH
NYLON SPINNERS LTD.
Pontypool, Mon.

MINISTRY OF SUPPLY Research and Development Establishments require ASSISTANT EXPERIMENTAL OFFICERS, and EXPERIMENTAL OFFICERS (minimum age 27) in areas including Farnborough (Hants.), Bedford, Aberporth (Wales), Salisbury (Wilts), Malvern (Worcs.) for experimental work in physics, electronics, aero, electronic and mechanical engineering, chemistry or mathematics, also in physics and electronics at R.O.F., Blackburn, Qualifications G.C.E. (Advanced level), pass degree, H.N.C. or City and Guilds Final Certificate of grouped course (Advanced Grade) in Telecommunications. Salary ranges : Assistant Experimental Officer £382 (age 18) – £670 (age 26) – £830 (male) ; Experimental Officer £954 – £1,166. Women's rates same by 1961. Promotion prospects. Opportunities to compete for established posts. Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A.436/9A.

UNIVERSITY OF READING

Applications are invited for a LECTURESHIP IN PHYSICS. An interest in solid state physics or in the design of electronic circuits or of control mechanism is desirable. Salary scale : Grade II — £900 × £50 – £1,300 ; Grade I — £1,300 × £50 – £1,350 × £75 – £1,650. F.S.S.U. benefits and family allowances are provided. Applications from candidates who cannot take up an appointment before October 1, 1960, will be considered but the successful candidate may take up the appointment earlier if he is able to do so. Further particulars may be obtained from the Registrar (Room 22, O.R.B.), The University, Reading, by whom application should be received by December 7, 1959. Late applications from abroad may be considered. Four copies of an application, with the names of two referees will be required.

UNIVERSITY OF READING

Applications are invited for a LECTURESHIP IN THEORETICAL PHYSICS in the Department of Physics. On the experimental side the main interests of the Department are in solid state physics and spectroscopy. An increasing amount of theoretical work is being carried out in association with the experimental work. Salary scale : Grade II – £900 × £50 – £1,300 ; Grade I – £1,300 × £50 – £1,350 × £75 – £1,650. F.S.S.U. benefits and family allowances are provided. Applications will be considered from candidates who cannot take up the appointment before October 1, 1960, but the successful candidate may take up the appointment earlier if he is able to do so. Further particulars may be obtained from the Registrar (Room 22, O.R.B.), The University, Reading, by whom applications should be received by December 7, 1959. Late applications from abroad may be considered. Four copies of an application, with the names of two referees will be required.

CENTRAL ELECTRICITY GENERATING BOARD

RESEARCH AND DEVELOPMENT DEPARTMENT

RESEARCH LABORATORIES, LEATHERHEAD, SURREY

ELECTRONICS AND INSTRUMENTS SECTION — Ref. PB/416

The expansion of the Section has created vacancies for **GROUP LEADERS AND OTHERS** for work in the following fields :—

(*a*) **SIMULATORS.**—The group will be employed on the development of electrical or electro-mechanical simulators as an aid to studying the performance and control of the national power network, individual generating stations, turbo-alternators, boilers, and other plant. Applicants should be experienced in the design and use of network analysers, etc.

(*b*) **DATA TRANSMISSION.**—The group will be employed on the study and development of digital data transmission and logging techniques and their application to the electricity supply industry in the metering, control and communication fields.

(*c*) **NUCLEONIC INSTRUMENTS.**—The group will be employed on problems of nucleonic and reactor control instrumentation, and in the evolution and development of new types of instrument where reliability is of paramount importance.

(*d*) **COMMUNICATIONS.**—The group will be employed on developing modern telecommunication techniques for the electricity supply industry, including line, carrier, V.H.F. and microwave radio techniques for voice and digital communication, telemetry, remote control and power system protection.

Group Leaders must have a good University Degree or equivalent qualification and, as well as being competent electronic engineers well versed in modern techniques, must have had specialist experience of work allied to that of the group for which they wish to be considered. Salaries will be on scales within the range £1,530 – £1,983 p.a. according to duties and responsibilities.

Applications for supporting staff will be considered from electronic engineers of at least H.N.C. standard, who have had appropriate experience. Salaries will be on scales within the range £1,195 – £1,775 p.a. according to duties and responsibilities.

PROTECTION AND SYNCHRONOUS MACHINE STUDIES GROUP — Ref. PB/414

CHARTERED ELECTRICAL ENGINEERS required for employment of the study of design of new forms of protective gear for use on the Board's network, on investigations into the performance of protective relays, and the behaviour of power networks and plant under transient conditions, involving the use of multi-channel magnetic data recording systems. Research is undertaken into the performance of high voltage switchgear and synchronous machines.

Salaries on scales within one of the following ranges, according to duties and responsibilities : £1,195 – £1,775 p.a. or, up to £1,300 p.a.

Applicants must have a University Degree or equivalent qualification, and for the higher posts, previous experience in power system protective relaying and high power transmission is essential.

GENERATION SECTION — Ref. PB/413

ENGINEERS, CHEMICAL ENGINEERS AND PHYSICISTS are required for the above section.

The successful candidates will join groups working on **HEAT TRANSFER** problems associated with the fuel elements and heat exchangers of both present and advanced types of nuclear power stations.

Investigations are being carried out on laboratory and pilot-scale plant, and are principally directed towards a better understanding of the fundamental mechanisms.

Salaries on scales within one of the following ranges according to duties and responsibilities : £1,195 – £1,775 p.a. or, up to £1,300 p.a.

Candidates for the more senior positions should have an Honours Degree and research emperience, preferably in the field of heat transfer or fluid dynamics ; for the other vacancies the minimum qualification is a Pass Degree, or equivalent, and applications are particularly invited from recent graduates.

TRANSMISSION AND DISTRIBUTION SECTION — Ref. PB/415

ENGINEERS AND PHYSICISTS are required for a number of appointments to support and develop existing research on problems under the following broad headings :—

A. (*a*) Investigations of lightning research phenomena ; the high-voltage impulse characteristics of insulation and equipment ; the protection of power systems against surges.

(*b*) High-voltage a.c. and d.c. characteristics of insulation and equipment ; investigation of corona loss, radio interference and induction from overhead lines.

(*c*) Problems associated with overhead conductors, fittings, busbars and station equipment, including the determination of electrical characteristics, ratings and electrodynamic forces.

B. Research on outdoor high-voltage insulators including the development of testing and recording techniques, studies of arc behaviour and the investigation of surface insulation faults.

Salaries will be on scales within one of the following ranges, according to duties and responsibilities : £1,195 – £1,775 p.a. or, up to £1,300 p.a.

Candidates for the more senior positions should have a University Honours Degree and relevant research experience. For the other vacancies, candidates should have qualifications at least equivalent to H.N.C. in Electrical Engineering or Physics.

Successful applicants for work under part B may be required to spend part of their time at Croydon or Brighton.

PHYSICS SECTION — Ref. PB/417

Applications are invited for two appointments in a group working on **ELECTRON MICROSCOPY AND DIFFRACTION** and **X-RAY DIFFRACTION** and **SPECTROSCOPY**. Candidates for post (*a*) should have had considerable experience in electron microscopy, particularly in the fields of metal physics or metallurgy. The successful candidate will be responsible for a Siemens Elmiskop I electron microscope, which is shortly to be installed, and will be expected to develop the use of the electron microscope in collaboration with the existing techniques of X-ray diffraction and X-ray spectrometry. Candidates for post (*b*) should be experienced in X-ray analytical techniques, preferably as applied to metallurgical problems.

The minimum qualification for either appointment is an honours degree or its equivalent.

Salaries will be on scales within the following ranges, according to duties and responsibilities :

Post (*a*) £1,195 – £1,775 p.a. Post (*b*) up to £1,300 p.a.

CHEMISTRY AND METALLURGY DIVISION — Ref. PB/428

PHYSICAL CHEMISTS AND PHYSICISTS required to work in a team investigating the **OXIDATION OF GRAPHITE** as it affects the operation of nuclear reactors. The work will include :—

(*a*) high vacuum techniques to study the kinetics of gas-solid reactions ;

(*b*) developing new techniques of infra-red analysis to investigate reacting systems ;

(*c*) applying microwave spectrometry to reacting systems ;

(*d*) mass spectrometry, where assistance is required in developing techniques for high speed measurements in ionized gas systems, as well as in applying conventional methods.

Candidates should have a good honours degree in chemistry or physics, or equivalent qualification and, for the more senior posts, should have experience in one of the above fields.

Salaries on scales within one of the following ranges according to duties and responsibilities : £1,195 p.a. – £1,775 p.a. or, up to £1,300 p.a.

Applications stating age, qualifications, experience present position and salary to the Personnel Officer, 24/30 Holborn, London, E.C.1, as soon as possible. Envelopes should be marked "Confidential," quoting relevant reference number.

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The Rôle of a Mathematical Machines Laboratory in Education

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(Imperial College of Science and Technology, London)

INTRODUCTION

STUDENTS of science and technology often have difficulty in applying mathematics to physical problems. Indeed, it has been observed that the less-gifted students frequently exhibit a positive dislike of mathematics which is probably due to

(*a*) their difficulties in formulating problems in mathematical terms,

(*b*) a feeling that there are, too often, " trick-steps "† in the chain of reasoning which the student feels himself unlikely to be able to invent as and when required,

(*c*) difficulties, or perhaps laziness, in translating the mathematical results into physical terms to the fullest extent.

Science and engineering teachers have perhaps a special responsibility for arousing interest in mathematics because, having themselves passed through similar educational processes and (one hopes) having overcome the difficulties mentioned, they should understand the students' problems far better than most mathematicians ever could. To teach mathematics itself as an abstract, logical discipline, is clearly the business of mathematicians, but the science or engineering teacher in applying mathematics to physical situations has a twofold role to play. He must explain just why a particular mathematical description is appropriate, and what approximations have been used ; and after the analysis, he must state in physical terms just what has been achieved. This is *not* the business of the mathematician. The second part of his role is to use physical apparatus to help to teach the applications of mathematics. Cf paramount importance in this context are analogue devices (e.g. the conduction analogue, for systems obeying Laplace's equation) and analogue computers (both mechanical and electronic). The former give practice in interpreting the same mathematical expressions in several different physical contexts—d.c. conduction, electrostatics, magnetostatics, steady-state heat flow, etc., for the case mentioned—and the latter contain components visibly obeying specific mathematical operations (such as addition, multiplication and integration) from which systems obeying differential and other equations can be built. The student seems to take to these devices with enthusiasm and with their help increases his ability to use mathematics itself. In most Mathematical Laboratories,(1) desk-calculating machines and automatic digital computers form the main part of the equipment. Where the object is to provide a computing service for the research workers in a university, this is undoubtedly the proper equipment although analogue computers also have a useful role in research work. Where the teaching of engineers and scientists is the main concern, however, analogue devices and analogue computers are essential.

The equipment of the ideal laboratory—which we prefer to call a Mathematical Machines Laboratory—would include :—

models and analogue devices
analogue computers (differential analysers)
punched-card machinery, analogue-digital converters, etc.
desk-calculating machines
digital computer
logical computer

The absolute minimum would be to put some models and analogues in the ordinary undergraduate teaching laboratories.

While the purpose of this paper is to emphasize the value of these devices as teaching aids in applying mathematics, the fact that they are now important

* Now at the University of Saskatchewan, Canada.

† For example, some of the substitutions needed to change integrals into standard forms. A plea must be made for the avoidance of " trick-steps " when possible, coupled with the admission that—where used—their discovery might hold up even a mathematician for a week. This sort of admission is very encouraging to the weaker student.

research tools provides a second good reason why their acquaintance should be made in undergraduate courses.

MODELS AND ANALOGUE DEVICES

Rather than survey the enormous number of useful models and analogues, consideration of two should serve to indicate our conclusions.

All students must understand simple harmonic vibrators, forced vibrations and resonance, and a set of simple pendulums of various lengths, driven through a common yielding support by a massive pendulum, has been found effective as a demonstration. The basic idea is that the application of a displacement to the point of support of a simple pendulum is equivalent to applying a force to the bob itself. Details are shown in Fig. 1 in

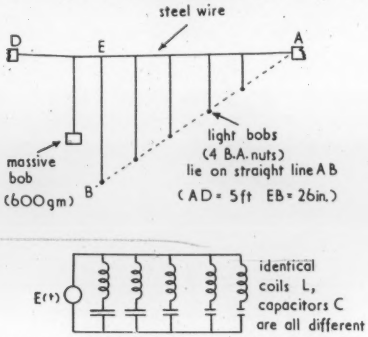

Fig. 1. *A set of simple pendulums and their electrical analogue.*

which the massive pendulum, swinging at right angles to the plane of the diagram, drives the light pendulums. If the movement of the **top** of the heavy pendulum is $X(t) = X_0 \sin \omega t$, the tops of the light pendulums move in proportion both to $X(t)$ and to their distance from A. It can then be shown that if $y(t)$ is the displacement of the bob of a particular driven pendulum of length l, that

$$\ddot{y} + (g/l)y \propto X(t) \qquad (1)$$

Fig. 1 also shows a set of electrical resonators, driven by a common e.m.f. $E(t)$, for which, if $q(t)$ is the charge on any particular capacitor C,

$$\ddot{q} + [1/(LC)]q = L^{-1} E(t) \qquad (2)$$

On comparing (1) and (2), it will be seen that if L is constant and C is proportional to the length l of the corresponding pendulum, the systems will be analogues of one another.

With the pendulums, the amplitude and phase relationships, corresponding with the well-known resonance curves for a set of lightly damped oscillators, are visible to the eye, and the transient vibration produced when the system is started up is also visible. The transient dies out in about two minutes during which beats can be seen between it and the steady-state vibration on at least one pendulum.

Two massive pendulums hanging from a taut horizontal wire provide a good demonstration of coupled oscillators for which the degree of coupling can be increased by slackening the wire. Beats can be seen between the two modes of vibration of the system.

There seems little point in specifically discussing the value of such demonstrations; it is so obvious. The apparatus should be permanently set up where the students can use it themselves when they wish—it is virtually student-proof.

One of the most valuable analogue devices, for field problems, is an electrical-conducting medium in which d.c. or low-frequency a.c. flows. The electric potential distribution obeys Laplace's equation and the system is an analogue of all the other physical systems which obey this equation. The best known practical form of this is the electrolytic tank, but, for student use, conducting paper (" Teledeltos paper ") to which electrodes of silver paint can be applied with a brush, seems better. The potential at any point is measurable by means of a d.c. potentiometer and galvanometer and a permanent map of the equipotentials can be rapidly produced. A great variety of experiments can be devised to suit every kind of student, from 1st year to postgraduate, whether physicist, electrical, mechanical, civil or aeronautical engineer. One can, for example, obtain values of capacitance between electrodes of awkward shape, or study the accumulation of electrostatic charges at sharp corners on conductors, or examine the potential distribution in a triode valve near cut-off—to mention but a few of the applications to electrostatics. The exercise of translating the results obtained on the conducting system into equivalent electrostatic ones is very valuable. Field quantities such as $-\frac{\partial V}{\partial x}$, grad V, $\int H.dl$, $\iint B.ds$ can be given some real physical meaning in the students' mind. Details of the application of the method to magnetic fields are given by Barker[2], to transient and steady-state responses of electrical networks by Boothroyd, Cherry and Makar[3], and Soroka[4] in a general account, deals with steady-state heat flow, diffusion and flow round aerofoils. In addition to carrying out a few field plots, and interpreting them himself, the student should have the opportunity of inspecting maps covering a wide range of fields.

ANALOGUE COMPUTERS AND SIMULATORS

Analogue computers are assemblies of several types of basic unit, a particular type of mathematical operation being associated with each kind, e.g., addition, multiplication and integration-with-respect-to-time. The interconnections between these units, making up chains and closed loops, force the system as a whole to obey some specific equations, and measurements made on the system can be used to solve those equations for specific values of the parameters in them.

That is how a mathematician would look at it. The scientist or engineer would in fact want to use the computer to deduce the properties of some other physical system and his first step would be to obtain a set of equations obeyed (within limits) by that physical system and then to build up a computer to obey them (again, within limits). The computer assembly is also a physical system and its measurable physical performance simulates that of the system being investigated; one system is an

analogue of the other. The difference between such analogue computers or simulators and analogue devices like the conduction analogue, is that the former are general-purpose devices and can be made to represent a new system merely by rearranging the interconnections between the units. From the educational point of view, the student can increase his appreciation of operations such as integration, and learn better the meaning of equations—particularly differential equations—in their physical applications.

There are two types of analogue computer especially suitable for teaching purposes, as distinct from problem solving, although they are important for the latter. The first is a new kind of mechanical analogue computer,* in which numbers are represented by linear displacements, and in which all movements are visible to the onlooker, and the second is the "repetitive" type of electronic differential analyzer which is dealt with later.

In the mechanical analogue computer, the interconnections which transmit the linear displacements from one unit to another are steel tapes in tension. Fig. 2 shows a hypothetical arrangement of units suitable for demonstrations and experiments. (It differs in a few particulars from the arrangement actually in use). To understand its action, the input to the top integrator at † is assumed to be d^3y/dt^3, and since integration is with respect to time the output is d^2y/dt^2; continuing round the figure in the direction of the arrows, it is possible to lable each input and output until, on arriving back at †, it is seen that d^3y/dt^3 is the sum of $f(t)$, the output from a graph follower, and $-(A\,d^2y/dt^2 + B\,dy/dt + Cy)$. Hence the system obeys a third-order linear differential equation with constant coefficients A, B, C. Such an equation has three arbitrary constants in its solution whose values are related to the arbitrary initial settings of the outputs of the three integrators. y and both its derivatives can be automatically plotted against time by the recording pens and it is also possible to plot one variable against another, e.g. to make phase-plane diagrams.

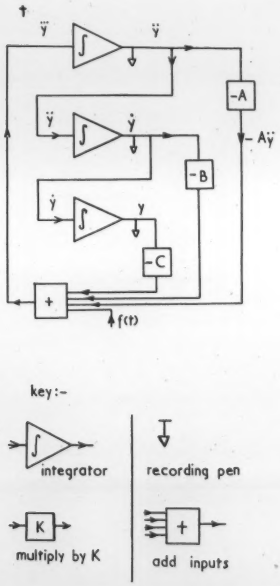

Fig. 2. *A differential analyser arrangement obeying* $\dddot{y} + A\ddot{y} + B\dot{y} + Cy = f(t)$

The study of the complete system—which can be adjusted to have one oscillatory and one exponential mode of motion—is naturally the climax of the student's experiment. In fact, he begins by examining the properties of the individual computing units, giving some attention to the errors inherent in them. If the coefficients A, B and C are all set to zero, $f(t)$ feeds an open-ended chain of three integrators in tandem and the results of repeated integration of $f(t)$ with respect to time t appear on the record. If $f(t)$ is a constant, then the successive integrals are, when graphed against time, a straight line, a parabola and a cubic. The output of the integrators at $t = 0$ is quite arbitrary and by changing these initial conditions, the intercept of the straight line, and the shapes of the parabola and cubic can be altered. When he has accounted for these effects, the student has a much better appreciation of the term "integration."

If the coefficient A has a non-zero value, but $B = C = 0$ still, the system obeys a first-order linear differential equation, and if A is positive, the equation is the same as that for the current in a series L-R circuit, $f(t)$ corresponding with the applied e.m.f. The time-constant can be measured on the record and compared with the theoretical value. However, a much more valuable exercise is to ask the student to find the time-constant of a given L-R circuit from a measurement made on the computer. This brings in the numerical values of physically analogous quantities and the ideas of scaling.

If $C = 0$ and both A and B are positive, the system obeys that second-order differential equation which describes a damped vibrator (if $A^2 < 4B$) and the computer does in fact produce a damped vibration when set into motion. The dependence of the natural frequency of the system on the value of B (when A is small), the prediction that critical damping occurs when $A^2 = 4B$, and that the system will be unstable if A is negative, can all be examined. It is instructive to examine the responses of a system which is nearly critically damped, to a pulse, step-function, ramp, and to sinusoids of various frequencies, because they correspond with the behaviour of moving coil meters to similar waveforms.

The electronic differential analyzer is also useful for educational purposes, particularly the "repetitive"

* Air Trainers Link Limited.

type of computer which can run quickly through the significant range of the solution and present the results on a cathode-ray-tube. Such computers are made up of units having roughly the same functions as those in the mechanical computer, but voltage (measured with respect to earth) is the analogue of number. The working of the electronic computing units is readily explained to electrical engineers and physicists, but other students would have some initial difficulty in understanding their action. In addition to the experiments described in connection with the mechanical computer, others can be performed which take advantage of the almost instantaneous response of the repetitive computer to changes in the numerical constants of the problem. Thus if the equations of some complex dynamic system have been set up, it is possible very rapidly to explore the ranges of the constants which give, for example, oscillatory rather than non-oscillatory behaviour to a disturbance, or a stable rather than an unstable response. On the mechanical computer, and on slower and more accurate electronic ones, it might take two minutes before it can be seen what type of response the system has to an applied disturbance.

The attractiveness of these computers to the students—and there is no doubt that they enjoy using them—lies in the fact that they are *physical* systems. Their skill in handling physical instruments, which is usually far greater than their skill in mathematical analysis, is brought fully into use. Skill in mathematical analysis cannot, of course, be acquired by using a computer, indeed its use is almost wholly avoided. The formulation of the problem in mathematical terms, and the interpretation of the results are required whether the problem is solved by computer, numerical method, or mathematical analysis, and the skilful use of approximations is common to all methods. These aspects of the problem are the ones which will be important to the student in his future career ; he can always consult a mathematician for help in analysis. It is worth noting that when non-linear units are involved, the solution of problems which are intractable by mathematical analysis, can be readily handled by computers, and this should be pointed out to the students.

Electronic computing units can be used for the automatic solution of simultaneous algebraic equations (especially linear ones). As an alternative to the automatic form, which sometimes may oscillate and prevent a solution being obtained, the Gauss-Seidel iteration process can be carried out. Many other types of analogue computing devices exist[4] but are not of such general application.

DESK CALCULATING MACHINES

Some numerical analysis should be taught in the ordinary mathematics courses, and exercises are essential. By the time the student reaches his third year, he should be ready to solve some physical problems with the aid of numerical analysis, and so get more practice in connecting up his mathematics and physics. These exercises provide a good opportunity for the student to learn to check his work properly so that, at the end, he is reasonably certain that his solutions are correct. Mathematical and/or numerical checking processes are an essential part of the technique of numerical analysis and these can—and must—be supplemented by dimensional checks on the correctness of equations and by careful examination of the final results (perhaps with the help of limiting cases) to see if they are compatible with the physics of the problem. In our experience, this insistence on checks comes as something of a surprise to the student but it is possible to persuade him to take an interest in them by pointing out his probable usefulness to his future employers if he does not !

Suitable mathematical tasks—which can be presented in physical contexts chosen to suit the type of student involved—are the solution of a polynomial equation, solution of simultaneous linear algebraic equations, and solution of a differential equation (e.g.—a marching problem involving a non-linear equation).

DIGITAL COMPUTERS AND DATA PROCESSING SYSTEMS

We have no direct experience ourselves in training students to program and use digital computers, but it is certainly essential for them to have some appreciation of the potentialities of these devices and these we have taught. As tools for learning better to utilize mathematics—which is the theme of this paper—they are definitely less important than analogue computers. On the other hand, the student should know why some problems involving vast quantities of arithmetic are so important, and the modes of thought involved in programing are sufficiently interesting to warrant some of his attention. The electrical engineer must also know something of electronic digital circuits.

The capital cost of a digital computer is so high that one would not be purchased unless the needs of the research program justified it. However, all students could have a few lectures on the subject and a demonstration of the nearest computer can usually be arranged.

Apart from the digital computer being used to solve equations, etc., arising in research programs, the direct conversion of analogue measurements in vast quantities (e.g. in wind-tunnel instrumentation), into digital form on punched cards, which can then be processed by a digital computer, is opening up possibilities of new and interesting experiments, hitherto impossible. Such experiments could not be tackled at all if readings had to be taken manually. This data-processing equipment seems bound to affect all branches of science and technology as the potentialities become more widely known. Now is the time for students to learn about them.

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Industry and the Sixteen-Year-Old*

By L. P. GRICE, B.Sc., A.M.I.E.E.

(General Electric Co. Ltd., Coventry)

ALTHOUGH my paper has for its title " Industry and the sixteen-year-old " I must admit, at the outset, that my own experience is entirely in the engineering industry and my remarks apply particularly to that industry. It is likely that they apply in some measure to a number of other industries as well but I make no claims about that.

This year about 776,000 children will reach the age when they may leave school. About three quarters of them will be coming into industry. What are the openings available to them ? Broadly they can be placed in the following categories :—

(1) Unskilled or semi-skilled work requiring only a little training.
(2) Craft apprenticeships.
(3) Technician apprenticeships.
(4) Professional training courses.

UNSKILLED OR SEMI-SKILLED WORK

Boys and girls taking employment in this category are usually put straight to work with people who are experienced in the job, and they are simply told to " sit by Nellie " and learn from her. In the engineering industry these boys and girls become, in the main, machine minders and assemblers. But as mechanization increases we need fewer people to do this unskilled repetitive work and more skilled people to make the machines and the tools.

Typical of this trend are the figures displayed in Figure 1. This shows the number of semi-skilled assemblers employed to produce a given number of television receivers.

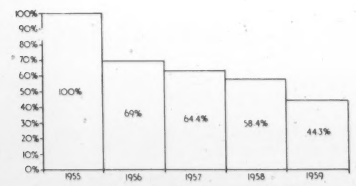

Fig. 1. *Unskilled labour required to assemble " X " number of television sets.*

We have a very long way to go before we reach the automatic factory but we are certainly on the road towards it.

CRAFT APPRENTICES

This category includes all the boys who are to become skilled with their hands. It includes a vast number of occupations and I do not propose to list them. Amongst them, however, are the instrument makers, tool makers, fitters, turners, glassblowers, electricians, plumbers, bricklayers, etc. In many cases there are agreements between employers and trade unions which govern the training which these boys receive. In nearly every case, the training course is of five years duration. Many of the bigger firms start their craft apprentices in an Apprentices' School. There is no doubt that this is the most satisfactory way of dealing with the basic training of apprentices. The old method of learning all the skill on the job is, at the best, a chancy and inefficient system. Unfortunately the vast majority of craft apprentices, and other apprentices too, still get all their training in this way. Sometimes they are taught wrong methods and it must be unusual for a boy to be placed with a man who is both highly skilled at his craft and a good teacher. In an Apprentices' School the instructors can be carefully chosen to fulfil both these requirements.

Having learnt his basic skills, the apprentice must then apply them in the normal conditions under which his particular craft is practised. This part of his training cannot be carried out effectively in a school and the apprentice must, at this stage, " go into the shops."

Most apprentices are allowed to attend their local technical college one day a week in order to learn the scientific and technical background of their craft. Most craft apprentices will follow City and Guilds craft courses or they may try to obtain National or Higher National Certificates in engineering. The very high failure rate in the National Certificate course has received wide comment in recent years. Are the courses unsuited to the students, the students unsuited to the courses or the technical colleges incapable of properly teaching the one to the other ? I am sure that the heart of the matter is that boys are not always put on to the course which best matches their intellectual ability. The startling figures of wastage on Ordinary National Certificate courses produced by Professor Lady Williams and independently by Dr. E. C. Venables, show this quite clearly. The figures shown in Figure 2 are collected from the intake to four technical colleges and they would appear to be fairly typical. Some firms, however, go to a great deal of trouble to place their apprentices on the most appropriate courses and do not

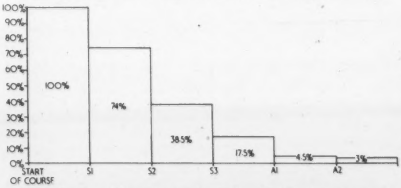

Fig. 2. *Apprentices studying National Certificate courses.*

* An address given at the Education Group Conference held in the Institute's House on April 3, 1959

allow their boys to start courses which they stand little chance of completing. In these cases the wastage figures are by no means so discouraging.

It is, of course, most important that *employers and parents* should do all they can to encourage the younger workers to gain qualifications. A man with a Higher National Certificate is virtually assured of a worthwhile job but it will take a student at least five years to reach this standard and he will have to be an unusually determined and persistent young man to reach his goal unless he receives encouragement from all quarters. An increasing number of firms have established prize schemes to encourage their apprentices to take their examinations and some give salary increases for examinations passed.

Most craft apprentices are " indentured or legally bound " to their employers for a specific period—usually five years. This is traditional but it is a practice which needs to be examined very critically. There is no doubt that boys acquire skills at very different speeds and of course they have different natural aptitudes. Yet it is most unusual to find employers who set their apprentices trade tests. Given the will by the employers and co-operation by the unions, there is no reason why such tests should not be devised. This should lead to a definite improvement in standards of skill and possibly to a shortening of apprenticeship.

TECHNICIAN APPRENTICES

The technician apprenticeship category is a comparatively new one and it is of increasing importance. The term " technician " can be defined in various ways but in general it covers those occupations which are below professional level but which need a combination of technical knowledge and some manual skill. A draughtsman falls into this category as do laboratory assistants and some testers. The range of occupations which technician apprentices can be trained to fill is very wide and the arrangements for technician training are very varied. Some employers have established four or five year training courses which are planned to give the apprentice a broad background knowledge of the industry during the early years of his training and a specialized knowledge in a particular branch during the latter years. The advantage of this is that a boy need not decide what line to specialize in until he has tried his hand at a number of things. This is indeed a very real advantage and by this means we can certainly place at any rate the majority of the square pegs into square holes. On the other hand there is a disadvantage in that during the early years of the course the apprentice may be wandering rather aimlessly from department to department. In my view this early training should be cut to a minimum and the boy's course made as purposeful and objective as possible at an early stage.

The standard of entry for technician apprentices varies widely. Many firms insist on a minimum of four or five Ordinary level passes in the General Certificate of Education and most insist on English language, mathematics and physics.

These boys will, in the main, study for National and Higher National Certificates although in some cases where there is an appropriate City and Guilds technician course available they may well study for this. As I believe there are a number of school teachers present to-day, may I make a plea that if boys are intending to make their future in engineering they should be encouraged to include amongst their G.C.E. subjects mathematics, English language and physics. Many boys take general science in the G.C.E. rather than physics, and this often puts them a year behind.

Now that more and more boys are staying in the sixth form, however, some firms are raising their standards of entry and are asking for an Advanced level pass in mathematics or physics for a technician apprenticeship. I expect to see this become more common and to see schemes introduced to train technicians in two years or perhaps even one year. This concentrated training could only be done in a special works training section and in close co-operation with the local technical college. Such a course might well be planned on a sandwich basis although it would not, of course, lead to a Diploma in Technology or to any other recognized technical qualification such as Higher National Diploma, during the training period. After the concentrated course of training the boys would acquire the rest of their knowledge on the job but would not be regarded as under training during that time. These people would, of course, be eighteen-year-olds and really they are outside the scope of my talk. I have, however, mentioned this as I believe this type of course will become more common during the next few years. Indeed, such courses would already have been planned if it were not for the National Service deferment regulations.

The fourth category of professional trainees is outside the scope of this paper as these young men would nearly all remain at school until the age of eighteen years.

INDUCTION

The change from school life to industry is very abrupt and all boys need as much help as possible to help them over this hurdle. Many employers recognize this problem and they help the new boy to settle into his job by providing an induction course. One of the objects of this course is to give the trainee a glimpse of the whole purpose of the works or industry and its relation to everyday life and its importance to the community. It should help him to build up a feeling of confidence in the firm and its management. The course should make clear how the trainee's work will fit in to the whole organization. It would include information on the firm's history, the company's organization, how the departments are connected and what opportunities there are for training and promotion. The firm's products and how they serve the community, the work's regulations including those on health and safety, why they are made and why they must be kept would all be discussed and canteen, welfare and recreational facilities enumerated. Each boy should know who to turn to if in difficulty and should have a clear idea of the training which will follow. This information will be imparted by means of talks, discussions, visits and, in some cases, by films. In this way the newcomer can be made to feel really welcome and will be given the sense of belonging to a team. Some induction courses are extremely good and boys going to firms which plan such courses get off to a really good start.

The school, too, can help a boy to overcome this hurdle by making his last year at school quite different from previous years. I am, of course, thinking here principally of boys who are not preparing for the General Certificate of Education examinations as in these cases the syllabus of the G.C.E. restricts what can be done. But for boys who are not preparing for the G.C.E. there is much to be said for giving them as much practical work as possible during the last year. Some schools I know have departed from the normal school curriculum and provide courses on such subjects as power supplies, communications—by road, rail and telephone, raw materials, public services, surveying and so on. Carefully selected works visits can also, of course, be very valuable.

SELECTION

Industry to-day is spending large sums of money on training and it is therefore important to put some effort into ensuring that boys are properly selected for the occupation they will be best suited for.

Most firms will claim to have a selection system but the methods adopted are extremely varied. There are still a few people about who claim to " know the winners as soon as they see the whites of their eyes " and there are other people whose judgement is affected by the applicant's resemblance to the interviewer or by his taste in ties.

Fortunately, however, there are many enlightened firms which spend much time and money in ensuring that they are getting the right kind of recruits. Basically, of course, employers are looking for the same qualities in their recruits and these qualities are assessed mainly as a result of interviews. The selection procedure used in my own department is based on the five-fold grading scheme as advocated by Munro Fraser. The qualities we are looking for are shown in Figure 3. The weight which one attaches to these qualities will vary with the type of apprenticeship the boy is being considered for. The boy who wishes to be a sales trainee should clearly rate highly in the first quality " First impressions and physical make-up." So, too, should the boy who wishes to become a production supervisor. The next thing we are looking for is the boy's qualifications and here we rely on fact and not on the judgement of the interviewer.

Assessment Sheet	"A" Grade Very much above Average	"B" Grade Above Average	"C" Grade Average	"D" Grade Below Average	"E" Grade Very much below Average
	20 19 18 17	16 15 14 13	12 11 10 9	8 7 6 5	4 3 2 1
FIRST IMPRESSION AND PHYSICAL MAKE-UP (Appearance, Speech and Manner. Health, etc.)					
QUALIFICATIONS (General Education, Vocational Training and Previous Experience)					
ABILITIES :—					
Verbal					
Perceptual					
Numerical					
Mechanical					
Spatial					
MOTIVATION (Level of Goals, Realism and Consistency in following them up.)					
ADJUSTMENT (Acceptability, Sense of Responsibility, Reliability and Leadership.)					

Fig. 3. *An assessment sheet for interviews.*

Perhaps the boy has taken G.C.E. or R.S.A. examinations, or if he has not taken public examinations we rely, to some extent, on reports given by headmasters. Dare I say that these vary in their value ? A point I should like to make here, however, is that we never ask a boy to bring his school reports with him as we regard them as confidential between the school and the parents. We then apply a number of tests to determine the boy's general abilities. These tests have been tried out on many thousands of boys and we believe that in conjunction with the other factors shown on the chart, they are reasonably reliable. Motivation is, of course, very important as we must be sure that our recruit will persevere with his training course. The depths of his interests at home and at school will help us to determine this. The boy's general adjustment to life is also very important as we must ensure that he will be acceptable to his work-mates and colleagues.

It must clearly be admitted that any selection procedure is fallible and even the most experienced interviewers make mistakes. We have found, however, that by using a system such as this and by ensuring that the interviewers are properly trained, the mistakes are kept to a minimum.

The process of selection should, however, be continuous. All apprentices are required to serve for a probationary period and if at the end of that time they are regarded as unsuitable for the occupation they have started in, it is not too late for the boys to be transferred to another course. Flexibility is highly desirable in training arrangements and a great deal is being done to place boys in their most appropriate occupation.

THE BULGE

At the outset of this paper I said that some 776,000 boys and girls would be leaving school this year. In the average of the post-war years up to 1956 this number was only 640,000. Yet the bulge is only just beginning to find its way into industry. The problem is, I'm sure, one with which you are all familiar and indeed, many of you as school teachers have been coping with it very successfully in the schools for some years. A glance at the chart (Figure 4) will remind you of the problem.

The Carr Committee rightly pointed out that the problem is mainly one of training. Unless something is done to solve this problem very quickly, we shall have a lot of disgruntled young men on our hands. But the Carr Committee's report was published about a year ago and there is still little sign of action. There has, of course, been no shortage of exhortation but this has not

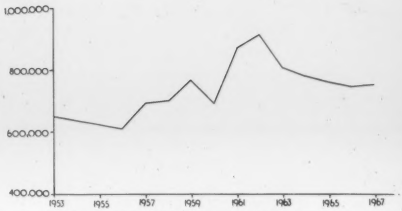

Fig. 4. *Extra people reaching working age.*

yet, and in my view is not likely to persuade firms to spend money on training more apprentices. Neither is it likely to persuade them to improve their present arrangements. My work keeps me in contact with a number of firms in the Midlands. I know of very few firms indeed who are proposing to recruit more apprentices to help with the bulge but I know of dozens who, for various reasons, are cutting down their recruitment of young people during the next year or two. Small firms in particular simply cannot afford to spend more money on apprentice training.

As long as we as a nation are prepared to leave apprentice training entirely in the hands of individual employers who will, quite understandably, and from their own point of view quite rightly, cut their intake of apprentices when they hit upon hard times, we are not going to solve the problem. We must not blame industry for the present state of affairs, for a firm naturally spends less when it earns less, and long term investments naturally give way to investments which will yield quick returns. Yet surely as a nation we must set standards of training which must be met by apprentices whether they are trained in good times or bad and whether by a large firm or a small one. Our future depends upon our being able to produce more goods of a kind which demand intelligence and skill in their manufacture. Therefore, we must ensure that there will always be plenty of trained people available for industry. Our present system of apprenticeship training which is inferior to that of many European countries is quite inadequate for this purpose, and it is high time that we did something about it. But it is unrealistic to leave this problem in the hands of individual manufacturers. If we are to produce the skilled people necessary for our survival as an industrial nation, it must be tackled on a national level.

Notes and News

Annual Dinner

The Annual Dinner will be held at the Park Lane Hotel, on Tuesday, May 3, 1960.

Television lectures

Because of the General Election, Sir Lawrence Bragg's series of television lectures mentioned in the October *Bulletin* were postponed. The series began on November 12 and will continue for six weeks.

Graduateship Examination : New Regulations

The Institute's Graduateship Examination will be held in an entirely different form from 1962 onwards. Instead of the present single examination there will be two parts. In Part 1 there will be three papers in physics and one paper in mathematics ; Part 2 will consist of four papers, of which three will be compulsory. The scheme is as follows :—

Part 1 Physics
- *a.* General physics and mechanics
- *b.* Heat and optics.
- *c.* Electricity.

Mathematics.

Part 2 *Three compulsory papers*
- *a.* Atomic and nuclear physics, electricity and magnetism.
- *b.* Optics, heat and thermodynamics.
- *c.* Properties of matter.

One paper chosen from :
- *d.* Mathematical physics.
- *e.* Electronics.
- *f.* Applied heat.
- *g.* Applied optics.
- *h.* High-energy radiations.

Detailed syllabuses will be available shortly.

No practical examination will be set but candidates will be required to follow approved courses which include practical work. Laboratory notebooks may be called for.

The pass list will be divided into " pass with honours " and " pass." The " pass with honours " will be accepted by the Institute for the purpose of election to Associateship on the same terms as approved degrees in physics with first and second class honours. The "pass" will be accepted for this purpose on the same terms as approved degrees in physics with third class honours.

Candidates who do not comply with the Institute's regulations relating to general education will be required to take a General paper.

New regulations incorporating these changes will shortly be available.

Exemptions

Exemptions from the whole examination will be given to holders of approved degrees, certain Diplomas in Technology and other qualifications specifically recognized. Exemption from Part 1 will be given to holders of degrees specifically recognized for this purpose (among which are Ordinary degrees with physics as one subject), and to holders of the Higher National Certificate in Applied Physics who have obtained an average mark of not less than 60% in the final examination for the Certificate. There will be no exemption from individual papers of either part.

Income tax relief on subscriptions to Institute journals

The Inland Revenue has agreed that those members of the Institute whose annual membership subscriptions qualify for relief under Section 16 of the Finance Act 1958 (see *Bulletin* for November, 1958, p. 281) and who pay an additional annual sum to receive the *Journal of Scientific Instruments* or the *British Journal of Applied Physics* or both may also be relieved under this Section in respect of the additional payment. Members should apply to their local Inspectors of Taxes to be allowed to deduct the payments from the amount of their emoluments assessable to income tax under Schedule E.

Physical Society Exhibition

The Physical Society's 44th Annual Exhibition of Scientific Instruments and Apparatus will be held in the Halls of the Royal Horticultural Society, Westminster, London, S.W.1, from January 18-22, 1960, inclusive.

Members of the Institute who are not members of The Physical Society may obtain tickets for the exhibition, available for any one day, on application to the Institute. A limited number of tickets for the members' session on the first morning are also available.

Orders for catalogues (price 6s. 0d. or by post 8s. 0d., available mid-December, 1959) are not being handled by the Institute but should be sent, with remittances, direct to The Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7.

Reviews of Books

BASIC PHYSICS OF ATOMS AND MOLECULES

By U. Fano and L. Fano

London : Chapman & Hall Ltd. Pp. xv + 414. Price 80s.

This book is directed primarily to research workers in the natural sciences and presupposes, therefore, only a general knowledge of physics and mathematics. It is in fact very well designed for postgraduate chemists, for example, provided they have not abandoned their mathematics too early in life. An attempt has been made to make the essential of quantum physics available to non-mathematical students, but the reader who needs the help of an appendix on complex numbers will have to be a very conscientious worker to get far through this book. On the other hand, the professional physicist, even at undergraduate level, should in some respects go beyond the scope of this book, especially in the calculation of detailed results.

The great virtue of this work is that the physical principles of quantum theory are brought out logically by reference to carefully selected experimental results—not necessarily those of most historical importance, but those of most pedagogic use. This removes those difficulties which arise from the common habits of teaching quantum physics either as a body of mathematical doctrine (generally presented without enough rigour to make it credible) or in historical sequence (meeting all the historic difficulties without resolving them decently). As a result, this is a first class quarry for teachers of quantum physics : the price alone makes one hesitate to commend it to students.

Comparing this book with the popular textbook by Bohm, which also contains extensive verbal discussions of physical principles, we find that this is harder, but more rewarding to study : Bohm of course goes much farther in the solution of problems and assumes a tougher mathematical background (though the reader who takes Fano and Fano's appendix VII with equanimity has nothing to fear in Bohm !)

A book aimed at the graduate schools of chemistry and engineering in the States has a limited potential readership in this country. Teachers of physics, and a few of the more serious chemists, will use it with profit.

G. Wyllie.

A HISTORY OF MATHEMATICS FROM ANTIQUITY TO THE BEGINNING OF THE 19th CENTURY

By J. F. Scott

London : Taylor and Francis Ltd. Pp. 266. Price 63s.

When writing a history of mathematics an author has to presume a certain knowledge of mathematics and general history by the reader. The author of this book presupposes a knowledge of mathematics up to "A" level and a knowledge of history to " O " level.

The treatment of mathematics in antiquity is adequate though perhaps somewhat conventional. The reviewer finds it difficult to agree with the author's statement that " the (Babylonian) contributions (to astronomy) were of a general nature and were in no sense scientific." A fairly elaborate account of Indian mathematical studies in the first millennium is given ; this is followed by the most extensive and valuable part of the book, the history of mathematics during the 16th and 17th centuries. The discovery of the calculus is described in detail, full justice being done to Newton and Leibmiz, while the claims of Barrow are not overlooked. The last chapters of the book, dealing with the 18th and the beginning of the 19th century, suffer from the fact that the author does not assume the reader to be familiar with the developments.

H. Heilbronn.

ELEMENTARY STATISTICAL PHYSICS

By C. Kittel

London: Chapman & Hall Ltd. Pp. ix + 228. Price 64s.

This book is based on lectures given by its distinguished author to beginning graduate students at Berkeley University as part of an American " graduate course." In this country it should be a most valuable aid to honours students of physics in their last year and also to postgraduate students, because a thorough understanding of the principles of statistical physics is nowadays essential for all physicists, when there is hardly any field of pure or applied physics where statistical considerations and methods have not to be used.

The book is divided into three parts. Part I is a beautifully clear presentation of classical and quantum-theoretical statistical mechanics and thermodynamics, based on the theory of ensembles. The theory is applied not only to problems usually found in textbooks on this subject but also to some topical problems of particular interest, like collisions of very high energy particles, " negative temperature " etc. There are, of course, a number of points on which one might hold opinions different from those of the author. One of these is the definition of temperature. According to the author the temperature of a system is defined by the temperature of a thermal reservoir with which it is in statistical equilibrium and therefore temperature fluctuations in the system have no meaning. But a more realistic definition of temperature is the " operational " definition by means of a suitable thermometer, and on the basis of this definition temporal and spatial fluctuations of temperature in a system have a well defined meaning.

Part II of the book is devoted to fluctuations, noise and irreversible thermodynamics. Here the author does not aim at presenting a logically built up theory of these phenomena but restricts himself to some of their most important aspects, like the Wiener-Kinchin and the Nyquist theorems, the Fokker-Planck and the Langevin equations, the Onsager reciprocal relations, and the principle of minimum entropy production in stationary processes.

Part III, entitled " kinetic methods and transport theory," is a collection of unrelated topics which do not

fit into the two previous sections but are essential parts of statistical physics, like relaxation problems, the Boltzmann transport equation and its applications, and the laws of rarified gases. An appendix finally deals with special mathematical methods used in statistical physics, like the method of steepest descent and the use of electronic computors for the solution of problems of molecular dynamics.

Although only a modest knowledge of mathematics and basic physics is required the book is by no means " elementary " and some chapters are of a fairly advanced character. It is a typical feature of the way in which the present generation of physicists is brought up that the author found it necessary to start the book with a brief chapter on Hamiltonian classical dynamics but takes it for granted that the reader is familiar with atomic physics and the principles of quantum theory. Whether this method of teaching physics is going to produce a better understanding of the fundamental principles remains to be seen.

A great number of applications of the general theory to special, interesting problems are given in the form of " exercises." Some of these are rather involved and certainly beyond the capacity of the average reader. It would be of great help if in a future edition the solutions of the problems would at least be indicated in an appendix.

Each single chapter is written lucidly and in excellent style, providing the reader not only with knowledge of the subject but also giving him æsthetic satisfaction. The book is beautifully printed and I could not find a single misprint or error in the mathematical formulae. It can be very warmly recommended.

R. Fürth.

EXPLORING THE STRUCTURE OF MATTER

By Jean-Jacques Trillat

London : George Allen & Unwin Ltd. Pp. 214. Price 30s.

This book, which is a translation of the original French version, contains a general account of the applications of electron microscopy and of electron and neutron diffraction, together with a brief discussion of microradiography by X-rays and electrons. That the book reflects so closely the author's own interests perhaps explains the rather strange omission of any comparable account of the applications of X-ray crystallography : in the absence of any comment on this feature the book seems oddly unbalanced.

Although the main emphasis is on the results obtained, the physical principles underlying electron microscopy and diffraction are briefly discussed and some of the relevant formulae are derived. But this is not a textbook, nor, in the reviewer's opinion, will the layman find it particularly intelligible although it contains much that would be of interest to him if he could understand it. This is essentially a book for general reading, by the physicist, chemist or metallurgist who is interested in a broad survey of the sub-microscopic structure of matter. The range of topics discussed, most of them only briefly, is very wide. It covers biological, chemical, metallurgical and physical applications and serves to illustrate well the versatility and power of the technique described. The book is copiously illustrated, although some of the line diagrams have a rather Victorian air, and many plates are well-chosen, well-reproduced and often very striking.

It is disappointing to have to report that the translation is not very well done, particularly in the first part of the book. There are passages where one's first reaction is that a line must have been omitted, others which are just awkwardly worded, and others which are just crude, e.g. a caption to a figure which reads " Diagram of the structure of ice after diffraction of X-rays." There has also been some carelessness in the reproduction of symbols and formulae, and not enough care has been taken to ensure that all the symbols are defined.

A. E. De Barr.

NUCLEAR THEORY

By L. Landau and Ya. Smorodinsky

London : Chapman & Hall Ltd. Pp. vii + 108. Price 45s.

No book by Landau can fail to be stimulating and informative, exciting and at the same time full of a ripeness that is the result of a deep understanding of the whole of physics. This slim volume is no exception and I am the better physicist for having read it. And yet I am dissatisfied.

This is a collection of lectures and it must have been a great experience to listen to them. But now that it is there on the printed page and one has time to stop and think, doubts creep in. There are far too many unproved statements, and when they are such that one cannot understand them or, worse, disagrees with them, then excitement turns to exasperation. Still, although even Landau cannot always be right and some of the statements in the book probably are wrong, I have no doubt that, as I read the book again and again, the number of those that I think wrong will decrease. This book then is not for the novice, but it is one that no nuclear physicist should fail to read at some stage of his career.

The subject matter covered is orthodox and includes the usual chapters on nuclear forces, nuclear structure and nuclear reactions. The book concludes with two chapters on π-meson physics which are already getting a little out of date, but that is a minor flaw. A more serious one—and one shared with other books on nuclear physics—is the attempt to introduce passim those aspects of quantum mechanics that just happen to be needed. This never fails to mystify the reader.

The translation seems very competent and the lecture style clearly comes through. It is a pity, however, that the symbol used for the infinitesimal element of volume is *do*. This Russian convention is not one to be encouraged here. The book is imported from the United States where it sells for $5·25. At the present exchange rate this is 37s. 6d. and for another 2s. 6d. a single copy can be sent across to this country. There seems no justification for raising the already high price even higher, to 5d. per page !

L. R. B. Elton.

BASIC PHYSICS

By Alexander Efron

London : Chapman & Hall Ltd. Pp. xii + 702. Price 62s.

This book certainly deserves a place in the Science library. The diagrams and illustrations are magnificent and the text very readable. In standard it is above G.C.E. " O " level but falls short of G.C.E. "A" level, and for both it is deficient in proofs. The price is too high for it to be used as a textbook. Some points require amendment in this country, e.g. density as weight of unit volume. Throughout the book, formulae are given without a vestige of a proof. Gay-Lussac's law in this country refers to the simple ratio existing between the volumes of gases reacting chemically with one another. It is a pity that the answers to the good and numerous examples are not given. Students should be encouraged to try more examples than those set to them, and they do not get satisfaction unless they can easily verify their answers.

In admiring the readable character of the text, two chapters seem to the reviewer to be models of their type, namely chapter 21 on the atom, and chapter 24 on nuclear energy. It is refreshing to note that " J " has at last been mentioned in the Honours list.

R. M. Lee.

ELEMENTARY ASTRONOMY

By Otto Struve, Beverly Lynds and Helen Pillans

New York : Oxford University Press. Pp. 396. Price 55s.

This book represents a novel enterprise, from which educational authorities anxious about guiding the current boom in physics and astronomy have much to learn. Astronomy is here developed not on the conventional descriptive lines but as chapters in the teaching of physics. This means that the book contains many worked numerical examples on topics not commonly exercised among casual or elementary readers, for instance on dimensions in binary star orbits.

This will be stirring news to those of us who have insisted that a student of physics is incompletely educated unless he sees the laws of his laboratory reproduced and extended in the sky. But English readers may be critical of the level at which the physical principles are introduced. The audience is presumably considered as American, but will they understand the excellent account of line spectroscopy as measuring degrees of ionization and relative abundance of elements in the solar atmosphere, when they are also supposed to need the very elementary description of what is meant by wavelength and that violet implies shorter wavelength than red ? Presumably the readers who take to the details of current research projects will omit the sections aimed at someone who has never heard of physics, and vice versa, and the range admits many kinds of " man in the street " although it is not easy to envisage the stage of university, technical college, or school at which the whole book will be read. But many of the shrewd and thoughtful numerical problems could well be tried by professor or his children with equal astonishment, as they illustrate intelligible developments in astrophysics which are unknown to readers of popular books or even large texts.

In England it is especially a happy privilege to welcome a general book by Otto Struve the senior author. He is, of course, the present member of a long family of Struves who have played a major part in the world's astronomy, until recently from Russia but now from U.S.A. The present Otto Struve has done more than anyone to elucidate from spectral line contours the complexity with which close binary stars eject gas from one component to the companion and to rotating gaseous rings. Needless to say, the sections in the book on binary stars are masterly as no other writer could make them ; but there is no overemphasis on favourite stellar topics, and another section of the book which ought to be read by all students of any physical science and shows unique power of clear exposition concerns our earth as a physical body.

Martin Johnson.

PROPERTIES OF MATTER

By F. C. Champion and N. Davy

Glasgow : Blackie & Son Ltd. Pp. xvi + 334. Price 40s.

A general criticism of textbooks on the properties of matter is that the subject is invariably presented to the reader in a form which gives the impression, rightly or wrongly, that the subject is of academic interest, the experiments are standard and classical, and that there is little fresh or exciting to learn about the physical properties of materials and our surroundings. But surely this is in disagreement with present-day research, where such a great deal of effort is being devoted to the study of the solid state, of the Earth and its surrounding atmosphere, and of the behaviour of materials under extreme conditions ! Champion and Davy's textbook is no different in this respect from other modern textbooks on the properties of matter. It clings to the old well-tried formulae, experimental methods and theories. Perhaps that is what the student wants, but the teacher of the subject would like something more stimulating and up-to-date.

This is the third edition of Champion and Davy's well-known textbook for the advanced undergraduate student of physics, and in spite of its shortcomings it will, like the previous editions, receive a very warm welcome. The second edition which appeared in 1952 differed in several respects from the original which was first published in 1936. Up-to-date, revised values for the fundamental constants were included in the second edition. A similar revision has been made for the present edition, and new data in accord with DuMond and Cohen's 1955 values are included. In the second edition, also, the older experimental methods were replaced by more modern and technically superior methods, but in the third edition there is little evidence of any similar improvement. Indeed most of the experiments described are pre-1930, and many of the bibliographical references are not the most recent or the best. (For example, on page 233, the references to textbooks on the kinetic theory of gases and vacuum technique are dated not later than 1927.) The main difference between the present and earlier editions is that, wherever possible without considerable disturbance to the text, the subject-matter has been re-orientated in

order to accord with the recent trend to relate the macroscopic properties of substances to their structures on an atomic or molecular scale. Since there are many new textbooks devoted exclusively to atomic physics, solid state physics, and the like, and very few to the phenomenological treatment, it is possible that many readers may regret the authors' new departure.

The treatment throughout the text is sound and the diagrams are clear. Familiarity with the calculus is assumed. There are minor blemishes and misprints ; the more obvious are the page heading on pages 5-11, the Pirani-Hall gauge on page 231, and the careless expression of pressure as so many mm.

S. WEINTROUB.

MAGNETIC SOUND RECORDING

By D. A. Snel

London: Cleaver-Hume Press Ltd. Pp. xii + 217. Price 25s.

FROM MICROPHONE TO EAR

By G. Slot

London: Cleaver-Hume Press Ltd. Pp. ix + 258. Price 21s.

Both these books appear to have been written for the amateur high-fidelity market which is rapidly expanding. There is, therefore, the maximum of practical hints and tips in both books and very little basic physical knowledge. The style, however, is quite lucid and they give a comprehensive survey of the field but are of little use to anyone seriously interested in the subject because there is a complete absence of references to the extensive scientific literature. However, although they are obviously intended for high-fidelity enthusiasts, they may be of some use in the training of operators of recording equipment. From the point of view of the physicist they are rather disappointing.

The first book *Magnetic Sound Recording* covers the field very comprehensively and there are chapters on amplifiers, loudspeakers and microphones. Hints are given on the making and replaying of recordings. The fields of stereophony, sound with films, broadcasting and television are touched upon.

The second book *From Microphone to Ear* concentrates more on details of disk recording and the replaying of gramophone records, but again amplifiers, loudspeakers and microphones are mentioned. There is a section on stereophony and a chapter on magnetic recording.

T. SOMERVILLE.

HIGH SPEED COMPUTING METHODS AND APPLICATIONS

By S. H. Hollingdale

London : The English Universities Press Ltd. Pp. xii + 244. Price 25s.

As applications and implications of computers become of increasing interest, enquiries are frequently made for a general introductory textbook suitable for unassisted study by those seriously interested but without previous specialized knowledge in this field. This book might well be made a first choice for this purpose by anyone from a managing director to a high-school pupil.

Starting from first principles and historical origins, it proceeds to characteristics and programming of machines, first in general terms, and then with specific reference to EDSAC and DEUCE—the computers which the author knows best, which differ sufficiently to make their joint consideration particularly instructive. With many detailed examples on counting, looping, iteration and modification, discussion continues up to the use of subroutines and assembly systems ; the reader would be enabled to write quite sophisticated programmes for both these machines, and many actual EDSAC or DEUCE users might be glad to have the book.

Storage systems and internal logical and circuit design are considered up to but not beyond the point where the consciousness and curiosity of the ordinary intelligent user are naturally stimulated. Chapters then follow on operating a computer service, and on applications generally (mathematical, engineering, commercial, even " fun and games " !). Three applications receive more detailed treatment—computer control of industrial processes and machine tools, simulation of probability-theory models, automatic language translation.

Throughout the book, many important topics receive incidental mention, with a length of treatment nicely commensurate with their general relative importance. The predominant impression left is of an excellently balanced introductory survey, which by itself will meet the needs of some, while adequately preparing others for the study of more specialized works.

T. H. O'BEIRNE.

THE PHILOSOPHY OF SPACE AND TIME

By Hans Reichenbach

New York : Dover Publications Inc. Pp. xvi + 295. Price $2.00

This book is a translation from the original German *Philosophie der Raum-Zeit-Lehre* published in 1928. That there should be a demand for such an enterprise some thirty years later is itself a tribute to the importance which scholars have come to attach to the author's researches during the intervening decades. It is perhaps permissible to recall at this length of time the impression which Dr. Reichenbach made upon those (the present reviewer included) who were at the Summer School of theoretical physics in Berlin in 1928. It was clear that a thesis of great moment was before us.

The discussion divides naturally into three parts—(1) space, (ii) time, (iii) space and time. Rather than follow this fundamental theme—now very largely accepted, except for certain developments—it may be more profitable to attempt a synoptic review of the position as it unfolded in the author's mind, and which therefore forms the characteristic basis of his thought. Fortunately, to this translation, Professor Rudolf Camap (who was associated with Reichenbach at the beginning) has been able to add a valuable contemporary introduction. In this way, the reader is helped to focus these rather difficult concepts upon the mental screen of present-day knowledge. As one would expect, apart from Riemann's metric, Euclid's parallel postulate is the starting point ; from its rejection much has been achieved, if by its retention much of practical value has been preserved. Incidentally, it has taken many

centuries to reach even approximate axiological balance, and the end is not yet.

It is, of course, only too obvious that the physicist must sooner or later decide by experiment—i.e. by measurement—in what sort of *space* we live. That he can do this for the analogous case of the *surface* of the earth is common knowledge. If, however, he is to work " outside " the earth effectively, he will need what Reichenbach calls the " principle of the elimination of universal forces." These are forces which (*a*) affect all materials in the same way, and (*b*) against which there are no insulators. Heat, for example, is evidently not a universal force. The proposal to accept such a definition of " rigid body " and " measuring standard " with respect to which all universal forces vanish, is the writer's main contention and perhaps his most original contribution.

There are, moreover, two very significant instances of perception—or perhaps better, visualisation—which are far too little known. One is the demonstration that *within a circle*, it is possible to sense the relation between Euclidean chords, and non-Euclidean straight lines through a given point. The other is that a four-dimensional continuum [say $f(x,y,z,t)$] can, in a very limited degree, be apprehended by substituting some physical factor—e.g. colour—for time. Billiard balls would then only be in four-dimensional contact if they were of exactly the same " colour." If this changed continuously and ever so slightly, they could be said to be receding.

Although much water has passed under the bridges since the book was written, in translation it is well worth while, and on the whole is both readable and idiomatic; a very appropriate memorial to its distinguished author.

F. I. G. Rawlins.

CLASSICAL MECHANICS

By J. W. Leech

London : Methuen & Co. Ltd. New York : John Wiley & Sons Inc. Pp. ix + 149. Price 12s. 6d.

Classical Mechanics, that is the development of Newton's laws of motion into generalized forms suitable for all types of co-ordinate systems, formed the basis and inspiration for the newer concepts of Wave Mechanics. The book under review is a concise and well written introduction to both Quantum and Relativity Mechanics, via the traditional paths of Langrangian and Hamiltonian Functions and Variational Principles. There is no doubt that this approach is of the greatest educational value, and in fact has been taken by more than one author in the past. The special features of this book are the fullness of its explanations, making it suitable for undergraduate readers, and the depth of its probing into underlying suppositions. It has the appearance of a write-up of the methods of an exceptionally good teacher of applied mathematics. Its ranking as an "introductory account " rather than a standard textbook is due mainly to the lack of exercise questions. As a reliable guide through some very tricky mathematical country, this small inexpensive book will be the friend of many a student.

I. I. Berenblut.

SCIENCE STUDENTS' GUIDE TO THE GERMAN LANGUAGE

By A. F. Cunningham

London : Oxford University Press. Pp. xiii.186. Price 12s. 6d.

This is an excellent book for anyone who wants to learn German thoroughly ; if he were to learn all that is in the book, he would be able to read any German text with ease and carry out a German translation faultlessly, with one proviso to be mentioned below. He would not learn to speak colloquial German, for which an entirely different approach would be necessary. The approach chosen is systematic, simple and thorough; the introduction of the various stages of grammar and syntax is supplemented by suitably chosen and adapted German texts, for practice in reading and translation. There are most useful notes on the use of the dictionary, the author deliberately excluding vocabularies, from the eminently sound point of view that their inclusion would merely stop the student from learning how to use the dictionary. Almost one half of the book is given over to texts covering various branches of science, and indeed the only specifically scientific aspect of the book lies in the exclusive choice of reading material of that type.

The book does not provide a short cut to learning technical German. It may well be argued that no short cut is possible, and that one would either have to learn a language properly and systematically or not at all. I am satisfied that this argument does not apply to all people, and that it is possible to get a working knowledge of a foreign language with a minimum of systematic knowledge. All that is necessary is to get one's teeth into the new language, preferably by living in the country in question, or where that is not possible, by listening to the radio and by doing translations. If the material for these translations is from a field with which one is familiar, it will be found that after mounting the first hurdle, the task gets simpler and simpler, until no difficulty is experienced with such texts.

One would wish that the teachers of foreign languages would provide us with a book which would enable one to pick up a language in that way, which has many obvious advantages. However, the unsystematic nature of that approach most probably presents the teacher with an impossible task.

One other point of warning may not be amiss. Even the most successful pupil of a language is incapable of turning out an entirely successful translation in a technical field with which he is not familiar. Not even a textbook such as that under review is capable of coping with the difficulty that in any one field of science and technology there develops in each language a jargon which can be followed and translated only by someone thoroughly familiar with the subject. Herein lies the difficulty under which professional translation bureaux often have to labour. There is no substitute for reading in foreign languages, and one hopes that the present book will enable many students to do their own reading of German texts.

W. F. Berg.

National Certificates in Applied Physics: 1959 Examinations

Although the number of candidates for National Certificates in Applied Physics is small in comparison with the number of entrants for the much longer established certificates in engineering, the rate of growth is very satisfactory, as the following figures show.

	1953	*1954*	*1955*	*1956*	*1957*	*1958*	*1959*
Candidates for Higher Certificate	55	75	82	146	182	246	296
Candidates for Ordinary Certificate	151	206	309	424	456	637	820

Details of the 1959 results are given below. The certificates are awarded jointly by the Institute and the Ministry of Education (or the Scottish Education Department); the Institute is responsible, through its assessors, for the maintenance of the standard of the final examination. This year the assessors were:—

England and Wales

Physics - - - Professor J. D. Craggs
Applied Physics - Mr. A. E. De Barr
Mathematics - - Dr. J. Crank

Scotland

All three subjects - Dr. J. M. Valentine

Full details of courses for these certificates may be obtained from the Deputy Secretary.

	Ordinary National Certificate			**Higher National Certificate**					
							Distinctions		
College	*Candidates*	*Passes*	*Failures*	*Candidates*	*Passes*	*Failures*	*Physics*	*Applied Physics*	*Mathematics*
(*a*) England and Wales									
Acton : Brunel College of Technology	—	—	—	13	8	5	1	—	2
Bedford : Mander College	17	10	7	—	—	—	—	—	—
Birmingham College of Technology	—	—	—	11	6	5	—	—	1
Birmingham: Matthew Boulton Technical College	26	18	8	—	—	—	—	—	—
Bournemouth Municipal College of Technology and Commerce	11	9	2	9	5	4	—	—	—
Brighton Technical College	11	9	2	6	6	—	1	1	1
Bristol College of Technology	8	5	3	—	—	—	—	—	—
Cambridge : Cambridgeshire Technical College and School of Art...	6	6	—	—	—	—	—	—	—
Cardigan Grammar School	9	5	4	—	—	—	—	—	—
Chelmsford : Mid-Essex Technical College ...	10	2	8	—	—	—	—	—	—
Connah's Quay : Flintshire Technical College ...	5	2	3	—	—	—	—	—	—
Croydon Technical College	15	11	4	10	5	5	—	—	2
Crumlin : Technical College of Monmouthshire	12	10	2	9	8	1	3	2	—
Derby College of Technology	7	7	—	—	—	—	—	—	—
Ewell County Technical College	23	17	6	—	—	—	—	—	—
Farnborough Technical College	51	45	6	—	—	—	—	—	—
Guildford County Technical College	16	13	3	30	28	2	9	2	16
Harrow Technical College	20	9	11	—	—	—	—	—	—
Kettering Technical College	16	10	6	—	—	—	—	—	—
Kingston Technical College	19	13	6	—	—	—	—	—	—
Leeds College of Technology	10	8	2	—	—	—	—	—	—
Letchworth : North Herts Technical College ...	32	24	8	7	6	1	2	—	1
Liverpool : City of Liverpool College of Technology	22	17	5	17	8	9	3	2	1
London : Northampton College of Advanced Technology	11	10	1	36	23	13	2	7	4
South-East London Technical College	63	35	28	16	10	6	—	—	3
Northern Polytechnic	30	18	12	—	—	—	—	—	—

College	Candidates	Passes	Failures	Candidates	Passes	Failures	Distinctions: Physics	Distinctions: Applied Physics	Distinctions: Mathematics
Newbury : South Berkshire College of Further Education ...	70	43	27	—	—	—	—	—	—
Oxford College of Technology	30	20	10	15	8	7	1	—	—
Preston : Harris College of Further Education ...	16	7	9	3	3	—	1	1	—
Reading Technical College...	49	35	14	17	12	5	1	1	3
Rotherham College of Technology	16	11	5	10	10	—	5	2	3
Rugby College of Technology and Arts	18	10	8	4	4	—	—	—	2
Salford : Peel Park Technical College	27	20	7	—	—	—	—	—	—
Salford : Royal Technical College	—	—	—	17	14	3	3	1	—
Salisbury and South Wilts College of Further Education	6	2	4	—	—	—	—	—	—
Southend-on-Sea Municipal College	23	13	10	17	15	2	—	—	4
Stafford : County Technical College	10	4	6	—	—	—	—	—	—
Stoke-on-Trent : North Staffordshire Technical College	10	4	6	7	7	—	—	—	1
Sunderland Technical College	33	17	16	11	5	6	—	—	—
Swansea Technical College...	4	3	1	16	12	4	2	2	4
Weybridge: Brooklands County Technical College	4	4	—	—	—	—	—	—	—
Whitehaven College of Further Education ...	6	3	3	—	—	—	—	—	—
Worcester : Victoria Institute	6	6	—	—	—	—	—	—	—
TOTAL	778 [40 Colleges]	515	263	281	203	78 [21 Colleges]	34	21	48
(*b*) SCOTLAND									
Aberdeen : Robert Gordon's Technical College	6	5	1	1	1	—	—	—	—
Thurso Technical College	6	4	2	—	—	—	—	—	—
Coatbridge Technical College	4	2	2*	—	—	—	—	—	—
Dundee Technical College	4	3	1*	—	—	—	—	—	—
Edinburgh : Heriot Watt College...	1	—	1	—	—	—	—	—	—
Paisley Technical College	21	12	9†	14	10‡	4†	1	—	1
TOTAL	42 [6 Colleges]	26	16	15	11	4 [2 Colleges]	1	—	1
GRAND TOTAL ...	820 [46 Colleges]	541	279	296	214	82 [23 Colleges]	35	21	49

* includes one candidate referred in one subject
† includes two candidates referred in one subject
‡ includes one candidate awarded certificate after being referred in one subject in 1958

Forthcoming Institute Meetings

Date	Place	Speaker	Title	Time	Branch or Group
Nov. 16	**Aberdeen** The University	Dr. G. Wyllie, F.Inst.P. (*University of Glasgow*)	**Dielectric polarization and absorption**	7.45 p.m.	Scottish
Nov. 16	**Manchester** College of Science and Technology	Dr. R. L. F. Boyd (*University College, London*)	**High altitude research during the International Geophysical Year**	7.00 p.m.	Manchester and District

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
Nov. 17	**London** The Institute's House	Dr. R. L. F. Boyd (*University College, London*)	**Some techniques and results of space exploration**	6.00 p.m.	London and Home Counties jointly with Electronics
Nov. 20	**Swansea** University College	Dr. J. G. Dawes, F.Inst.P. (*Safety in Mines Research Establishment, Sheffield*)	**Physics and the Safety in Mines Research Establishment**	5.15 p.m.	South Wales
Nov. 20	**Bournemouth** Municipal College of Technology and Commerce	Dr. R. L. F. Boyd (*University College, London*)	**Some techniques and results of space exploration**	7.30 p.m.	London and Home Counties jointly with the Mid-Southern Counties Section of the Royal Institute of Chemistry
Nov. 23	**Edinburgh** The University	Professor H. A. Brück, F.R.S.E. (*Astronomer Royal for Scotland*)	**Structure and evolution of the galaxy**	7.15 p.m.	Scottish
Nov. 24	**Glasgow** The University	Professor H. A. Brück, F.R.S.E. (*Astronomer Royal for Scotland*)	**Structure and evolution of the galaxy**	7.15 p.m.	Scottish
Nov. 25	**London** The Institute's House	Mr. J. F. Coales, O.B.E., F.Inst.P. (*University of Cambridge*)	**Education for automation**	6.00 p.m.	Education
Dec. 2	**Durham** Science Laboratories	Professor C. C. Butler, A.Inst.P. (*Imperial College of Science and Technology, London*)	**The British national hydrogen bubble chamber project**	5.30 p.m.	North-Eastern
Dec. 2	**Sheffield** The University	Professor S. Tolansky, F.Inst.P., F.R.S. (*Royal Holloway College, Egham*)	**The micro-structures of surfaces**	5.00 p.m.	Yorkshire
Dec. 3	**Liverpool** The University	Mr. E. W. Walker (*Atomic Weapons Research Establishment, Aldermaston*)	**High speed photography**	7.00 p.m.	Liverpool and North Wales jointly with Students' Physical Society
Dec. 4	**Bristol** College of Technology	Dr. R. L. F. Boyd (*University College, London*)	**Space research**	7.00 p.m.	South Western
Dec. 4	**London** The Royal Society of Tropical Medicine and Hygiene	Dr. H. Kaiser (*Institut für Spektrochemie und Angewandte Spektroskopie*)	Group Annual General Meeting followed by a lecture on **Time-resolved spectroscopy**	2.15 p.m. 3.00 p.m.	Applied Spectroscopy
Dec. 7	**Edinburgh** The University	Dr. G. Wyllie, F.Inst.P. (*University of Glasgow*)	**The new realism of physical theory**	7.15 p.m.	Scottish
Dec. 8	**Glasgow** The University	Dr. G. Wyllie, F.Inst.P. (*University of Glasgow*)	**The new realism of physical theory**	7.15 p.m.	Scottish
Dec. 9	**London** The Institute's House	Sir Edward C. Bullard, F.R.S. (*University of Cambridge*)	**Geological time**	6.00 p.m.	London and Home Counties
Dec. 10	**Birmingham** Regent House	Professor N. F. Mott, F.Inst.P., F.R.S. (*Cavendish Laboratory, Cambridge*)	**Recent work on dislocations**	6.30 p.m.	Midland
Dec. 11	**London** The Institute's House	Mr. J. F. Sayers, Grad.Inst.P. (*Atomic Energy Research Establishment, Harwell*)	**The ultrasonic camera—an alternative approach to ultrasonic testing**	6.00 p.m.	Non-Destructive Testing
Dec. 11	**Cardiff** University College	Dr. J. A. Pople (*National Physical Laboratory, Teddington*)	Branch Annual General Meeting followed by a lecture on **Nuclear magnetic resonance in liquids**	6.15 p.m.	South Wales
Dec. 14	**Manchester** The University	Mr. R. H. Litherland (*School of Art, Salford*)	**The aesthetic design of scientific instruments**	7.00 p.m.	Manchester and District

The Register

ELECTIONS TO MEMBERSHIP

THE FOLLOWING ELECTIONS WERE MADE BY THE BOARD ON OCTOBER 6, 1959

An asterisk (*) indicates transfer from another grade

FELLOWS (11)

*Ayliffe, Stanley Howard, B.Sc., Ph.D., Head of Physics and Mathematics Department, College of Technology, Bristol.

Bok, Bart Jan, Ph.D., Professor of Astronomy, Australian National University.

*Hawkes, John Crosfield, B.Sc., Manager, Physical Methods Section, Monsanto Chemicals Ltd., Ruabon, Denbighshire.

Head, John Waldegrave, M.A., Mathematical Consultant, British Broadcasting Corporation, Tadworth, Surrey.

*Hibberd, Francis Harold, M.Sc., Ph.D., Senior Lecturer, University of New England, New South Wales, Australia.

*Kaufman, Sydney, B.Sc., Ph.D., Senior Lecturer, Hebrew University, Jerusalem, Israel.

Langridge, Arthur, M.Sc., Chief of Physical Research, Westinghouse Brake and Signal Co. Ltd., London.

*Olsen, Jorgen Lykke, B.A., D.Phil., Privatdozent, Swiss Federal Institute of Technology, Zürich, Switzerland.

Pancholy, Maganial, M.Sc., Ph.D., Senior Scientific Officer, National Physical Laboratory, New Delhi, India.

*Vodden, Herbert Alfred, B.Sc., Group Leader, Monsanto Chemicals Ltd., Ruabon, Denbighshire.

*Wrist, Peter Ellis, M.A., M.Sc., Manager, Paper Manufacturing Research, Mead Corporation, Chillicothe, Ohio, U.S.A.

ASSOCIATES (45)

*Ansell, Richard Sydney, B.Sc., Advanced Development Engineer, Siemens Edison Swan Electric Co. Ltd., Cosmos Works, Enfield, Middlesex.

*Boyle, Hugh McFadyen, B.Sc., Senior Engineer, The Plessey Co. Ltd., Ilford, Essex.

Cameron, Antony John Wesley, B.Sc., Ph.D., Graduate Trainee, The Shell Company of South Africa Ltd.

*Cheetham, Ivan Clifford, B.A., Research Physicist, Dunlop Rubber Co. Ltd., Fort Dunlop, Birmingham.

Clarke, David Herbert, B.Sc., Ph.D., Member of Scientific Staff, The General Electric Co. Ltd., Wembley, Middlesex.

Curry, Norman Alfred, M.A., Senior Scientific Officer, Atomic Energy Research Establishment, Harwell, Berks.

*Dardis, John Gerard, M.A., Ph.D., Department of Physics, University of Kentucky, Lexington, U.S.A.

Dash, Bibhu Prasad, M.Sc., Ph.D., Research Geophysicist, Federal Government of West Germany, Hanover.

Davies, Ernest Arthur, B.Sc., Ph.D., Research Physicist, Metropolitan-Vickers Electric Co. Ltd., Trafford Park, Manchester.

*Dimes, Roy Edwin, B.Sc., A.R.C.S., Lecturer, Kingston Technical College, Surrey.

*Duggan, Thomas Cecil, B.Sc., Temporary Senior Physicist, Western Regional Hospital Board, Glasgow.

*Farmer, Anthony Arthur, B.Sc., Physicist, U.K. Atomic Energy Authority, Chapelcross Works, Dumfriesshire.

*Fitch, Robert Keith, B.A., M.Sc., Assistant Lecturer, College of Technology, Birmingham.

Foster, Basil Bernard, B.Sc., Development Engineer, Standard Telephones and Cables Ltd., London.

Ghosh, Dilip Kumar, M.Sc., D.Phil., formerly Research Fellow, University of Birmingham.

Grainger, Colin Trevor, M.Sc., Lecturer, University of New South Wales, Australia.

Griffiths, William James, B.Sc., Assistant Technical Manager, Philips Electrical Industries Pty Ltd., Sydney, Australia.

Hadden, Richard John Bayley, B.Sc., Senior Scientific Officer, Atomic Energy Research Establishment, Harwell, Berks.

Hall, David Newman, M.Sc., Ph.D., Lecturer, Kingston Technical College, Surrey.

*Hayes, David John, B.Sc., Experimental Officer, U.K. Atomic Energy Authority, Springfields, Preston, Lancs.

*Hill, Robert Mount, A.R.C.S.T., Ph.D., Research Officer, C.S.I.R.O., Sydney, Australia.

Hooton, Ivor Noel, M.A., Experimental Officer, Atomic Energy Research Establishment, Harwell, Berks.

Hutchinson, Frederick, B.Sc., Ph.D., Senior Physicist, Eastern Regional Hospital Board, Dundee, Scotland.

Hutton, Violet Rosemary Strachan, M.A., Lecturer, University College of Ghana.

Kerr-Grant, Colin, B.Sc., B.A., Reader in Geophysics, University of Melbourne, Australia.

*Latey, Clive Wyatt, B.Sc., Lecturer, College of Food Technology, Weybridge, Surrey.

Lee, Norman, B.Sc., Ph.D., Head of Applied Science Department, Dudley and Staffs. Technical College, Dudley, Worcs.

Levin, Michael Leon, B.Sc., A.R.C.S., Ph.D., Scientist, National Coal Board, Mining Research Establishment, Isleworth, Middlesex.

McCandless, Robert, B.Sc., Senior Science Master, Henry Mellish Grammar School, Nottingham.

Mahanty, Jagadishwar, M.Sc., Ph.D., Post-Doctoral Research Associate, University of Maryland, U.S.A.

*Matthews, Graham George, B.Sc., Ph.D., Section Leader, C. A. Parsons & Co., Ltd., Newcastle-upon-Tyne.

Neufeld, Edgar Leslie, B.Sc., Ph.D., Physicist, Mullard Research Laboratories, Salfords, Surrey.

*Noakes, Peter William, B.Sc., Development Engineer, Muirhead & Co., Ltd., Beckenham, Kent.
Organ, Robert Muller, Senior Experimental Officer, British Museum, London.
*Page, Ernest Basil, B.Sc., Physicist, Plessey Nucleonics Ltd., Northampton.
Rees, David John, B.Sc., Deputy Chief Physicist, National Centre for Radiotherapy, Sheffield.
*Richardson, John Franklyn, B.A., Ph.D., Research Physicist, Metropolitan-Vickers Electric Co., Ltd., Trafford Park, Manchester.
Roughton, John Edward, B.A., Physicist, Radiation Ltd., London.
Scott, Cyril, B.Sc., Major R.A., Technical Staff Officer, School of Artillery.
Smith, Leslie Maurice, B.Sc., Physicist, Dominion Laboratory, D.S.I.R.O., Wellington, New Zealand.
*Thornton, Eric, M.Sc., Physicist, North Thames Gas Board, London.
*Vulkan, George Hans, B.Sc., Scientist, National Coal Board, Mining Research Establishment, Isleworth, Middlesex.
*Wall, Howard, B.Sc., M.A., Lecturer, Wandsworth Technical College.
*White, Martin, B.Sc., Ph.D., Lecturer, Brighton Technical College, Sussex.
*Wood, Raymond Maurice, Technical Officer, Imperial Chemical Industries Ltd., Metals Division, Birmingham.

GRADUATES (89)

*Adam, Glennis Lois, Junior Physicist, E.M.I. Electronics Ltd., Hayes, Middlesex.
Adamson, Daniel Welsh, B.Sc., Graduate Apprentice, Siemens Edison Swan Ltd., London.
Allen, Geoffrey Albert, B.Sc., Postgraduate Student, University of London.
Anderson, Kenneth James, B.Sc., Experimental Officer, U.K. Atomic Energy Authority, Capehurst, Chester.
Atherton, Brian Godfrey, Junior Scientist, Vickers Research Ltd., Weybridge, Surrey.
Audus, Michael Francis, B.Sc., Assistant Experimental Officer, U.K. Atomic Energy Authority, Harwell, Berks.
*Baggott, Roger, B.Sc., Scientific Officer, U.K. Atomic Energy Authority, Springfields Works, Salwick, Lancs.
*Barry, Bryan Edward, B.Sc., Research Student, University of Edinburgh.
*Bell, John, Apprentice Physicist, The Plessey Co. Ltd., Swindon, Wilts.
*Berger, Ernest John, Technical Assistant, Wray (Optical Works) Ltd., Bromley, Kent.
Bett, Norman, B.Sc., Senior Research Physicist, Cambridge Instrument Co. Ltd., Cambridge.
*Bevan, Hugh, B.Sc., Technical Officer, British Nylon Spinners Ltd., Pontypool, Mon.
Birchall, David Robert, B.Sc., Research Student, University of Leeds.
*Boyer, Roy, Observer, British Cotton Industry Research Association, Shirley Institute, Didsbury, Manchester.
*Burn, Neil, B.Sc., Physicist, Courtaulds (Canada) Ltd., Ontario, Canada.
*Byrnes, Richard John, Junior Engineer, Rank Citel Ltd., London.
Cambey, Leslie Alan, B.Sc., Teaching Fellow, University of New South Wales, Australia.
Chadderton, Lewis Taylor, B.Sc., Research Student, University of Cambridge.
*Charles, Desmond, B.Sc., Assistant Technical Officer, Imperial Chemical Industries Ltd., Kynoch Works, Birmingham.
Coles, Robert Edward, B.A., Research Assistant, Cavendish Laboratory, Cambridge.
*Cropper, Frank Brian, Laboratory Assistant, Dunlop Rubber Co. Ltd., Manchester.
*Daniels, David John, B.Sc., Graduate Apprentice, Mullard Radio Valve Co., Mitcham, Surrey.
*Davies, Lynn, B.Sc., Research Student, University College of Wales, Aberystwyth, Cards.
*Dougal, Richard Crombie, B.Sc., Research Student, University of Edinburgh.
Eames, Harold William, B.Sc., Assistant Lecturer, South East Essex Technical College, Dagenham, Essex.
Elliott, Michael John Way, Experimental Officer, U.K. Atomic Energy Authority, Harwell, Berks.
Farrar, David Morton, M.Sc., Experimental Officer, Department of Scientific and Industrial Research, Harmondsworth, Middlesex.
*Fleming, Peter, Assistant Experimental Officer, Microbiological Research Establishment, Porton Camp, Wilts.
Fontaine, Alec Ernest, B.Sc., Assistant Physics Master, Scunthorpe Grammar School, Lincs.
*Foord, John Frederick, B.Sc., Physicist, De Havilland Propellers Ltd., Hatfield, Herts.
French, Ronald Lionel Douglas, B.Sc., Assistant Experimental Officer, U.K. Atomic Energy Authority, Seascale, Cumberland.
Gallagher, Charles, B.Sc., Teachers Training Course, Jordanhill Teachers Training College, Glasgow.
Gill, Kenneth Michael, B.Sc., Assistant Experimental Officer, Atomic Energy Research Establishment, Harwell, Berks.
*Harrington, Ronald Denis, B.Sc., Assistant Physics Master, Raine's Foundation Grammar School for Boys, London.
Harris, Leslie Bevan, B.Sc., Senior Scientific Officer, British Iron and Steel Research Association, London.
Hawkes, Geoffrey Allan, B.Sc., Experimental Officer, Aeronautical Research Laboratories, Melbourne, Australia.
*Herbert, Harold, Assistant Experimental Officer, Royal Aircraft Establishment, Farnborough, Hants.
Hoare, Denis, B.Sc., Research Student, University of Birmingham.
Hodgkinson, John Addy, B.Sc., Lecturer, Kingston-upon-Hull Technical College, Hull, Yorks.
Hough, Ronald, B.Sc., Physics Master, Licensed Victuallers School, Slough, Bucks.
*Hunt, Leslie Brian, Instrument Technician, Steel Co. of Wales, Port Talbot, Glam.
Hutchings, John Brian, Technician, Unilever Ltd., Sharnbrook, Bedford.

Iggulden, Leonard Charles, B.Sc., Assistant Master, Bournemouth School, Hants.

Inman, Clifford, B.Sc., Teacher, Beamont Secondary Technical School, Warrington, Lancs.

*Irving, William Robert, Technical Assistant, British Petroleum Co. Ltd., Middlesex.

Jefferys, Robert Charles, B.A., Assistant Experimental Officer, Armament Design Establishment, Fort Halstead, Kent.

Johnson, Margaret, B.Sc., Assistant Mistress, Enfield County School, Middlesex.

*Lamb, David Alexander Angus, B.Sc., Computer Development Engineer, Ferranti Ltd., Bracknell, Berks.

Livingston, Leslie David, Technician, Shell Refining Co. Ltd., Cheshire.

Lucy, George Thomas, Experimental Officer, Atomic Weapons Research Establishment, Aldermaston, Berks.

McCarthy, Brian Dennis, Development Engineer, Rank Cintel Ltd., London.

*McClure, Richard John, Electronics Engineer, Benson-Lehner Corporation, California, U.S.A.

Macpherson, Ian George, B.Sc., Assistant Physics Master, George Heriot's School, Edinburgh.

*Mason, David Bernard, Junior Technical Officer, National Institute for Medical Research, London.

Meats, Ronald James, B.A., Research Physicist, Metropolitan-Vickers Electric Co. Ltd., Trafford Park, Manchester.

Moelwyn Hughes, Ifan Gruffyd, B.Sc., Computer Engineer, Electric and Musical Industries Ltd., Hayes, Middlesex.

*Moore, John Keith, Assistant Experimental Officer, Royal Aircraft Establishment, Farnborough, Hants.

*Norman, Shirley, B.Sc., Laboratory Assistant, Courtaulds Ltd., Droylsden, Manchester.

*Obioha, Eugene Nwene, B.Sc., Senior Science Master, Iheme Memorial Grammar School, Noizuogu, Nigeria.

*Overton, Thomas Rumney, B.Sc., Research Student, Department of Medical Physics, University of Leeds.

Parker, Brian Henry, B.Sc., Physicist, The English Electric Co. Ltd., Whetstone, Leicester.

*Parry, Norman Courtnay Jordan, Assistant Experimental Officer, Armament Research Development Establishment, Fort Halstead, Kent.

*Perry, Donald Garth, B.Sc., Electronic Engineer, Electric and Musical Industries Ltd., Hayes, Middlesex.

Puddephatt, Roger Elston, B.Sc., Development Engineer, Ferranti Ltd., Wythenshawe, Manchester.

Ralf, Geoffrey James, Technical Assistant, Associated Electrical Industries Ltd., Aldermaston, Berks.

Reid, Alan, B.Sc., Assistant Experimental Officer, U.K. Atomic Energy Authority, Springfield Works, Salwick, Lancs.

*Richardson, Brian Arthur, Assistant Experimental Officer, Royal Aircraft Establishment, Farnborough, Hants.

*Richardson, Brian Hall, Technical Assistant, Mond Nickel Co. Ltd., Birmingham.

Rixon, James, B.Sc., Assistant Experimental Officer, U.K. Atomic Energy Authority, Culcheth, Warrington, Lancs.

Roberts, Joseph Ian, B.Sc., Technician, A. V. Roe & Co. Ltd., Woodford, Cheshire.

*Roberts, Ronnie, B.Sc., Science Master, Llanelly Girls' Grammar School, Carms.

Rose, Randal Maxwell, B.Sc., Lecturer, Old Swan Technical College, Liverpool.

Rycott, Peter David Dudley, B.Sc., Technical Engineer, Black-Clawson International Ltd., Kent.

Roskilly, Ian Graham, Assistant Experimental Officer, Armament Design Establishment, Fort Halstead, Kent.

Satchell, David William, B.Sc., Scientific Staff, The General Electric Co. Ltd., Wembley, Middlesex.

Slifkin, Michael Arthur, B.Sc., Research Student, University of Manchester.

Scriven, Alan, B.Sc., Research Assistant, Babcock & Wilcox Ltd., Renfrew, Scotland.

Shadbolt, Michael John, M.A., Capacitor Engineer, Standard Telephones & Cables Ltd., Paignton, Devon.

*Smith, John Edwin, B.Sc., Graduate Physicist, Dunlop Rubber Co. Ltd., Birmingham.

Snowden, Shirley Anne, B.Sc., Physics Mistress, Allerton High School, Leeds.

*Tatham, Alan Eric, B.Sc., Research Student, University College of North Wales, Bangor.

Taylor, Ronald Kenneth, Technical Assistant, Associated Electrical Industries Ltd., Aldermaston, Berks.

*Terry, John Owen, National Service.

Townsend, Derek John, B.Sc., Research Physicist, Westinghouse Brake and Signal Co. Ltd., London.

Turner, Alan Edgar, B.Sc., Physicist, Nuclear Power Plant Co., Knutsford, Cheshire.

Venables, John Anthony, B.A., Research Student, Cavendish Laboratory, Cambridge.

Watson, John Michael, M.Sc., Assistant Lecturer, North Staffordshire Technical College, Stoke-on-Trent.

*Wells, Colin Richard, B.Sc., Experimental Officer, Post Office Research Station, Dollis Hill, London.

Whitten, Edward William, Assistant Experimental Officer, Atomic Weapons Research Establishment, Aldermaston, Berks.

Eighty-nine Students and two Subscribers were also admitted.

The Institute's Journals

PRINCIPAL CONTENTS OF THE OCTOBER, 1959, ISSUES

Journal of Scientific Instruments : Volume 36, No. 10

High intensity, high speed, multiflash apparatus. By G. Dixon-Lewis and E. G. Jackson.

An apparatus has been constructed to provide a number of high-intensity xenon flash discharges at time intervals from 0·1 to $2{\cdot}5 \times 10^{-4}$ s between flashes, each flash dissipating 300 W.s in approximately 180 ms. Two flash-head arrangements were used: in one, the tubes were mounted on a rotating disk thus giving a series of flashes from one fixed position, whilst the other consisted of a stationary bank of tubes, the location of the individual tubes determining the position of each flash.

Neutron diffraction instruments at a high-flux nuclear reactor. By G. E. Bacon, F.Inst.P., and R. F. Dyer.

A description is given of an assembly at a high-flux reactor of two instruments for neutron diffraction measurements. One is a large instrument for use with polycrystalline samples: the other, much smaller, is for single-crystal work. An account is included of the associated in-pile equipment and shielding for producing the collimated beams of thermal neutrons.

Hydraulic oscillator for the dynamic calibration of pressure recording systems. By A. W. Melville.

An instrument is described which is designed to provide a constant-amplitude variable-frequency pressure cycle in a liquid, suitable for the determination of the frequency response of precision pressure transducers of low-volume displacement. The natural frequency of the fluid filled oscillator is 630 c/s.

Capillary pH electrode. By R. H. Wilkinson.

A robust glass electrode and stable liquid junction is described. The precision for venous blood is $\pm 0{\cdot}0015$pH unit over the range 20 to 40°C under strictly anaerobic conditions.

Apparatus for the measurement of internal friction and dynamic Young's modulus at kilocycle frequencies. By E. W. Dickson, A.Inst.P., and H. Strauch.

Electrostatic transducers are used to excite and detect longitudinal vibrations in a rod specimen clamped at its mid-point. The electronic circuit forms a regenerative loop in which oscillations occur at the resonance frequency of the specimen. A method of calculating the amplitude of the specimen oscillations is given. Measurements of the internal friction and dynamic Young's modulus, which can be made as a function of strain amplitude and temperature up to 500°C, are illustrated by some preliminary observations on beryllium.

Precision microphotometer for use with a Vickers projection microscope. By S. M. Makin and G. T. Rogers.

A microphotometer has been designed to measure photographic density and density gradients in autoradiographs. The equipment is designed to be used with a Vickers projection microscope, being particularly useful in the quantitative study of autoradiographs from metallurgical specimens. Results can be obtained over a magnification range of 18·6 to 400 times. The photographic density is measured by balancing the output of two photomultipliers, one in the incident beam and one in the transmitted beam. Densities measured on this instrument were compared with the quoted values on a standardized density wedge and gave a standard deviation of 0·006.

Continuous deionized water washing system for semiconductor devices. By V. J. Jennings and R. D. Knight.

Designed for use on a batch production basis, the apparatus provides for the recirculating water to pass through an ion exchange resin after washing the devices. Two conductivity cells, one on either side of the washing point, measure the specific resistivity of the circulating water; this is $20 \times 10^6 \Omega$ cm at 18°C in water about to pass over the devices, i.e. deionized water. The apparatus is constructed mainly of polythene and P.V.C. to avoid contamination of the water.

Characteristics of spark counters. By A. El-Nadi and F. M. Aly.

The spark counter, operating as an α-particle detector, has been studied extensively both with respect to the corona current in a given gas, and for different gases. The performance of a single wire counter was first studied, and then the experiments were extended to multiple wire counters. Nitrogen showed good characteristics with a single-wire counter, but failed for multiple wires, whereas dry air showed the best characteristics with a counter with six wires.

Design for an autographically recording tensile machine. By M. A. Adams.

An improved "hard" type tensile machine is described, designed primarily for metallurgical usage. Compactness and mechanical simplicity are combined with maximum accessibility of the load measuring device and specimen, and the load is measured with an electro-mechanical dynamometer which is easily adapted into a system for autographically recording the load-elongation curve. The machine should be particularly useful for dry-box or hot-cell work.

Device for the estimation of the rate of work on passing air by sine wave flow. By E. A. Cooper.

In investigating the resistance to airflow of equipment for respiratory protection, it is often desirable to know the rate of work done in sine wave flow. A device is described which allows this estimation to be made without intermediate calculation from the results of simple experiments carried out under conditions of constant rates of flow. If these results, when plotted on logarithmic paper as pressure against rate of flow, lie on a straight line, the device allows a second line to be drawn which represents the rate of work done in sine wave flow plotted against the volume moved per minute.

Simple electronic scanning system for the X-ray microanalyser. By A. Bernard, D. Bryson-Haynes and T. Mulvey.

An electrostatic deflector system is described for use with the X-ray microanalyser. This enables the electron probe to be scanned across the specimen electrically using either manual or electronic control. The application of this system to a current metallurgical problem is described and certain statistical limitations of the method are mentioned.

British Journal of Applied Physics : Volume 10, No. 10

SPECIAL ARTICLE

Nuclear magnetic resonance in solids. By E. R. Andrew.

The basic principles of nuclear magnetic resonance are discussed in elementary terms and an outline is given of the apparatus needed to detect the phenomenon. After brief reference to other uses, the application of nuclear magnetic resonance to solids is discussed in more detail. An account is given of the various interactions which generate the resonance spectrum and of associated spin-lattice relaxation mechanisms.

CONFERENCE REPORT

Summarized proceedings of a conference on precipitation in alloys and on metal structures—London, November, 1958.

A joint conference of the X-ray Analysis and Electron Microscopy Groups of The Institute of Physics was held in London on November 28, 1958. The subject of the conference was precipitation in alloys. On the following day the X-ray Analysis Group discussed metal structures.

ORIGINAL CONTRIBUTIONS

Estimation of trace water content in a halogenated oil by means of tritiated water. By J. F. Cameron and I. S. Boyce and R. M. Glaister, A.Inst.P.

A simple but accurate method using tritiated water for determining the efficiency of a plant for drying a halogenated, hydrocarbon oil is described. By the use of tritiated water with an activity of 50 mc/ml., it is possible to measure water contents as low as 0·04 p.p.m., while, with an activity of 5 c/ml., the sensitivity may be increased to four parts in 10^{10}. An advantage of the method is that the samples may be exposed to the atmosphere for short periods without appreciably changing the labelled water content.

Interferometric measurement of small angular displacements. By P. Hariharan, A.Inst.P, and D. Sen.

A modified three-beam interferometer is described for the measurement of small angular displacements. The instrument is extremely sensitive to angular displacements in a specified plane and is capable of a high degree of accuracy. In addition it is easy to handle and quite stable, since it is relatively insensitive to angular displacements in any other plane and is also completely unaffected by a linear translation of the detecting element.

Refrigeration of a superconducting memory for a computer. By A. C. Rose-Innes.

An estimate is made of the refrigeration, in terms of consumption of liquid helium, required to maintain at low temperature a memory of superconducting cells. Using commercially available cable, the major source of heat is thermal conduction down the leads to the memory. If a cable of low thermal conductivity is used, a memory of one million cells should not consume more than about 2 l. of liquid helium per hour. In an appendix, the optimum size for copper electrical leads running directly from room temperature to liquid helium is calculated.

Study of gas-lubricated, hydrodynamic, full journal bearings. By S. Whitley and C. Betts.

The two most important characteristics of gas-lubricated, full journal bearings are load-carrying capacity and half-speed whirl. In this paper these two characteristics have been investigated. The gases used as lubricants were mainly hydrogen, nitrogen and neon, giving a large viscosity variation; argon and carbon dioxide were also used to investigate the effect of the ratio of specific heats (γ). The bearings used were plain cylinders with a longitudinal groove cut into the upper surface of each bearing, extending over half the bearing length. It had been shown previously that this groove improved the half-speed whirl characteristics, and tests on bearings without the groove, included in the paper, demonstrate that the groove does not affect the load capacity.
The parameters investigated are bearing length, diameter, clearance, rotational velocity, ambient pressure, and the gas viscosity and ratio of specific heats. It is shown that, in general, the existing theories of load performance for compressible lubricants, operating in isothermal conditions, give a satisfactory correlation with the experimental results. The half-speed whirl results are not related to a complete analytical theory, but useful stability criteria are established.

Experimental method of investigating stresses in buttress dams. By J. R. Rydzewski.

A photoelastic method is described for investigating the stress distribution in a buttress dam web of constant thickness, resting on an elastic foundation. The method is also applicable to the stress analysis of a gravity dam. The general case is considered when the elastic properties of the foundations differ from those of the material of the dam. The investigations were made by "frozen-stress" methods in which the composite model of the dam and foundations, together with its impounded liquid, was subjected to a centrifugal acceleration which amplified the body forces and liquid pressures about twenty-eight times. The model was analysed in a polariscope to obtain the difference of the principal stresses and their directions, while the sum of the principal stresses was found from measurements of the lateral extensions of the model. For the latter purpose a new technique was developed.

PRINCIPAL CONTENTS OF THE NOVEMBER, 1959, ISSUES

Journal of Scientific Instruments : Volume, 36, No. 11

Semi-automatic control system for producing constant cooling rates. By L. W. Phipps, A.Inst.P.

This control system was designed and is best suited for cooling, at a constant rate, the metal sample block of a differential thermal analysis apparatus used for studying supercooling, melting and solidification phenomena in organic materials. An automatically-controlled flow of liquid refrigerant, passing through a simple heat exchanger, is used to cool the primary liquid circulating continuously in the coil system of the block. The apparatus is also suitable for uniform cooling of a small water or oil bath. For either application, controlled cooling rates of up to about 2° C/min are attainable. Using refrigerated water, control is possible from 95 down to about 10°C depending on the rate, but the range could be extended to lower temperatures by the choice of suitable liquid coolants.

Surge diverters using trigatrons. By T. E. Broadbent and A. Fernández.

The work described shows that a single-stage trigatron surge diverter is a simple and effective method of removing the voltage from a specimen once the breakdown initiation

process occurs. With solid specimens, the device is of value in enabling breakdown tracks to be observed, whilst with gaseous specimens the diverter can conveniently be used in the study of the filamentary discharges which occur during the breakdown initiation process. The results of detailed experiments designed to investigate the performance of trigatron surge diverters at direct voltages up to 1000 kV are discussed.

Apparatus for combined thermal analysis and dilatometry. By J. H. Pearce and P. G. Mardon.

An apparatus is described for carrying out simultaneous differential thermal analysis and dilatometry on small metallic samples at temperatures up to 1200°C in a vacuum. Automatic temperature control and recording are important features of the method, and a discussion of the chief sources of error is given.

Improved apparatus for floating-zone melting by electron bombardment. By F. E. Birbeck and A. Calverley.

An improved apparatus for floating-zone melting by electron bombardment is described. Provision is made for zoning speeds of 0-350 cm/h with bombarding voltages up to 10 kV at 500 mA. The operating vacua are of the order 10^{-6} mb or better. Up to 22 cm of specimen length can be zoned.

Improved microbeam back-reflexion X-ray camera with arrangement for irradiating a pre-selected area. By H. M. Otte and R. W. Cahn, A.Inst.P.

An improved camera is described for use in conjunction with a microfocus X-ray tube. It has the advantages over previous cameras of being more rapid and precise in setting and of enabling much shorter exposure times to be used for X-ray beams of 10 to 50 μ in diameter.

Torsion-effusion apparatus for the study of vapour pressure of alloys. By J. N. Pratt and A. T. Aldred.

A simple apparatus for the direct measurement of vapour pressures of metals by the torsional deflexion of an effusion cell is described. Results are given showing its use for the study of solid and liquid alloys. Its suitability for this purpose is discussed.

Direct stress machine for combined fatigue and creep testing. By A. H. Meleka.

The report describes the modifications introduced to a commercial creep testing machine so that tests under combined fatigue and creep conditions can be carried out. Results are given illustrating the performance of the converted machine. Limitations and further modifications are briefly discussed. The combined testing machine is now commercially available.

TIM; a brushless generating magnetometer. By C. W. McCutchen.

TIM (the turbo-inductor magnetometer) is an air-driven generating magnetometer which uses inductive output to avoid brushes and slip rings. The resulting mechanical simplicity allows TIM to be made very small while the high rotational speed, which is possible because there are no brushes, makes TIM quite sensitive. It is most suitable for measuring static or very nearly static magnetic fields. The output is an audiofrequency signal, and the accuracy depends chiefly on how accurately the amplitude and frequency of that signal are measured.

Simple electrical analogue for the solution of linear simultaneous equations. By D. B. Dove.

A simple resistance analogue provides a rapid solution for simultaneous equations of the type

$$y_i = a_{ij}x_j, \text{ where } a_{ij} = 0,\ i > j.$$

Single pen, strip chart recorder for unattended long period operation. By C. J. Sumner.

A battery operated recorder is described which is designed for operation for periods of 6 to 12 months without attention. It is suitable for recording such elements as water depth, rainfall, temperature, etc., and is provided with a solar time-check device which obviates the need for an expensive precision clock.

Recording is by a needle-pointed stylus which perforates the chart paper when depressed by a chopper bar. A relatively simple linkage is used to give a rectilinear traverse to the stylus.

British Journal of Applied Physics : Volume 10, No. 11

Some aspects of the design of large permanent magnets. By J. E. Cousins and W. F. Nash.

This paper considers the design and construction of a large permanent magnet for use in cosmic ray studies. It is shown that there is an optimum distribution of the magnetic material in order to obtain either a maximum field, H, or a maximum line integral, $\int_{-\infty}^{+\infty} H dy$, for a given pole face area and gap size. It has been shown that a good value of the leakage factor for use in the design calculations for magnets with rectangular pole faces can be prediced theoretically. Detailed comparison between results predicted by this theory and those obtained in practice with the present magnet and other large permanent magnets suggest that these calculations can be usefully applied to magnets with pole faces of any shape. These comparisons also show, in agreement with Andrew and Rushworth, that demagnetization curves for small specimens of magnetic material are not reliable where large blocks are considered.

Some aspects of the rheology of milk gel. By C. S. Landau, Grad.Inst.P.

Observations of the flow of milk gel have been analysed and shown to be in general agreement with Graham's theory of deformation. Individual creep curves are satisfactorily described by the sum of powers of time $t^{1/3}$, t^1 and t^3. The effect of stress on the creep of gels of various ages can be described by the sum of power terms with simple exponents. At small values of time, the strain recovered after removal of stress is proportional to the one-third power of time. There is general agreement between the predicted hysteresis loops and those observed in repeated loading tests.

Correction for size of cross-section of the secondary windings of mutual inductance standards of the Campbell type. By P. Vigoureux.

It is shown that the mutual inductance of standards of the Campbell type can be obtained with negligible error by replacing each turn of the secondary winding by a circle at the centre of the cross-section of the wire.

The total inductance is the sum of the inductances of individual circles; this sum is expressed by a formula which is shown to agree with Searle's formula provided the length and breadth of winding used in the latter are based on the mean spacing and the mean number of wires in the rows and layers.

Cathode work function, sparking potentials and secondary ionization coefficients for oxide-coated cathodes in hydrogen. By D. E. Davies, A.Inst.P. and B. J. Hopkins.

The Kelvin vibrating electrode technique has been applied to measure the contact potential difference between oxide-coated cathodes and a gold reference surface in the presence of hydrogen. Special high vacuum (Alpert) techniques were used to ensure high gas purity. By the use of both calcium

oxide and barium oxide cathodes, in various states of activation, it was possible to obtain a range of work function from 1·4 to 3·6 eV. Paschen curves were plotted for each of these oxide cathodes at room temperature, and minimum sparking potentials and secondary ionization coefficients were determined. A linear relation was found between the cathode work function and the minimum sparking potential. The slope of this line indicated that a 1eV change in work function corresponded to a change of 55 V in the minimum sparking potential. The slope of the line was confirmed by independent work function measurements using the graph of the Richardson thermionic equation. The curves (ω/α) v (E/p) showed a rapid increase in ω/α with decreasing values of E/p at $E/p < 100$ V/cm mm of mercury.

Influence of the cathode work function on the sparking potential in hydrogen. By D. E. Davies, A.Inst.P. and R. K. Fitch, Grad.Inst.P.

The Kelvin or vibrating electrode method of measuring contact potential differences has been used to follow changes in work function of evaporated metallic films in a parallel plate electrode system in hydrogen at about 10 mm of mercury pressure. A reduction in cathode work function of the order of 0·3 eV was effected by passing a current of 10^{-7} A for 10 s. After about 30 min the cathode work function returned to its original value. Similar treatment caused a reduction in the sparking potential of 30 V, which also returned to its original pre-discharge value in times of the order of 30 min. This, together with other experimental data, is consistent with the fact that positive ions from the discharge current remained on the cathode surface for periods up to 30 min after the current was switched off. It has been possible to demonstrate that, while these positive ions are being neutralized, there is a relationship between the work function of a cathode and its sparking potential in hydrogen.

Efficiency of characteristic K_α X-ray production in copper between 9 and 15 kV. By N. A. Dyson.

Absolute measurements are described of the production of K_α characteristic X-radiation in copper, and the data are compared with existing information. The measurements (together with a single existing observation) cover a range of electron energies between 9 and 15 kV.

Electrical conductivity of vitrain during carbonization. By M. I. Pope and S. J. Gregg.

Some vitrain samples, representative of the whole coal range, have been carbonized in oxygen-free nitrogen and their electrical conductivity measured *in situ*. The results have been interpreted in terms of the known processes occurring during carbonization.

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